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NATURAL PHILOSOPHY

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By W. H O O P E R, M. D.

V O L. II.

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RATIONAL
RECREATIONS.

VOLUME THE SECOND.

CONTAINING
EXPERIMENTS
IN
OPTICS, CHROMATICS,
AND
ACOUSTICS.



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DESCRIPTION of the PLATES.

PLATE I. p. 8.

FIG. 1. Shows the manner in which the rays of light converge and diverge.

Fig. 2. Different objects seen under the same optic angle.

Fig. 3. The refraction of a ray of light, AB, in passing through different mediums.

Fig. 4. The different sorts of lenses.

PLATE II. p. 12.

Fig. 1. The disposition of the lenses of a common telescope. AB the object-glass, CD the eyeglass; OI the object, which appears inverted at E, and magnified.

Fig. 2. The construction of a terrestrial telescope, in which the lenses CD and EF are added to those in the last figure, and by which the object is made to appear in its natural position.

Fig. 3. Shows the structure of a reflecting telescope. GH is a large concave metalline mirror,

perforated at *r*, by which the image of an object entering at the end of the tube *DE* is reflected to the small mirror *I*, placed on a stand, and by that to the glasses *B* and *A*, which convey it to the eye in an erect position.

Fig. 4. The construction of a double microscope. *AB* the object glass, and *CD* the eye glass: *gmh* the object, and *GH* the image, which appears inverted and greatly magnified.

P L A T E III. p. 36.

Fig. 1. Is a vessel with water, by the refraction of the light, through which three pieces of money *E*, *F*, *G*, are seen at the point where they were invisible before the water was poured into the vessel.

Fig. 2. Three small pieces of paper, *A*, *B*, *C*, being stuck against the wall, the image of one of them will at a little distance fall on the optic nerve at *D*, and therefore be invisible.

Fig. 3. The portable camera obscura. *E* is a plate of glass, placed in the frame *ABCD*, to which the image of the objects that enter the tube *O*, are reflected by the mirror *N*. The four legs and the pieces that compose the case *H*, have hinges, by which they fold up.

Fig. 4. The magic lantern. *ABCD* is a tin box, in one end of which is a concave mirror *G*; at the opposite end is a convex lens *L*, and before it a tin tube *O*, that has an opening *MN*, through which are passed the glasses that have the objects painted

painted on them. In the tube O is placed another that is moveable, and that contains two lenses P and Q, by which the objects on the glasses are thrown on the wall : K is a lamp, and E, F the funnel by which the smoke comes out, and its cover that keeps in the light.

P L A T E IV. p. 50.

Fig. 1, and 2. Are two plates of glass, to pass through the groove in the magic lantern at the same time, and by which the appearance of a tempest is to be exhibited.

Fig. 3. is a box that contains a chafing dish, on the smoke of which, that comes out at the top of the box AB, the figures of a magic lantern are thrown.

Fig. 4. A machine for representing a phantom : within it is placed a magic lantern, the images of which being reflected by the mirror M, pass out at an opening in the top of the box, and are thrown on the smoke of a chafing dish placed upon it, where they are visible.

Fig. 5. A large magic lantern for exhibiting a magical theatre. In the tube H are several grooves in different directions, by which different glasses are passed at the same time.

P L A T E V. p. 66.

Fig. 1. Representation of an object reflected by a plain mirror. AC the object, GI the mirror, DF the image.

A 4

Fig.

Fig 2. *GI* is a convex mirror, *AC* the object, and *DF* the image.

Fig. 3. *GI* a concave mirror, *AC* the object, *DF* the image, that appears behind the mirror, erect and magnified.

Fig. 4. *GI* a concave mirror, *AC* an object at a greater distance than in the last figure ; *DF* the image before the mirror, inverted and diminished.

P L A T E VI. p. 70.

Fig. 1. The Box for the boundless gallery: *EF* two pasteboards cut through, and painted on both sides ; *D* a pasteboard painted on one side only, and placed before a mirror at the end of the box ; *C* is the hole by which the objects are viewed.

Fig. 2, and 3. The painted pasteboards to place in the box, Fig. 1.

Fig. 4. The box for the four magical mirrors. *ABCD* the body of the box, against whose four insides the mirrors are placed. *BNLI* a frame of glass consisting of four inclined plates, and one at top that is horizontal ; by the latter the images placed on the bottom of the box are seen reflected by the mirrors.

Fig. 5. A plan for disposing the objects in the box, Fig. 4.

P L A T E VII. p. 80.

Fig. 1. The enchanted palace. Against the six pillars mirrors are fixed, that meet in the center, and between each triangular division objects are placed, that are reflected by the mirrors, *ABCDEF* is the plan of the base of the palace.

Fig.

Fig. 2. Is a square on which a regular figure is drawn, that when transferred to the corresponding divisions of Fig. 3, appears deformed, but when seen in a mirror placed at FG, from a point over B, appears exactly the same as on Fig. 2.

Fig. 4. The magical dial. In the drawer H is placed the dial Fig. 5, whose index is a touched needle that is moved by a magnetic bar under the dial-plate. At I another dial, Fig. 6, is placed, whose index is likewise a touched needle, and is regulated by that on Fig. 5. At M. is an inclined mirror, that, reflecting the dial placed at I, makes it visible at an opening in that center of the dial at the top of Fig. 4.

P L A T E VII. p. 92.

Fig. 1. The box of divination A B C D, in which are placed the tablets E, F, G, H, that each contains a magnet placed in a different position.

Fig. 2. The table, under which is a brass rod that has four pivots, to which are fixed the four pasteboard circles P, Q, R, S, Fig. 3. M N is an inclined mirror placed in a drawer under the table.

Fig. 4. Is the top of a box, that has three holes, and over them are placed three perspectives like Fig. 6. Each of these perspectives is fixed on a hollow pedestal, and contains a mirror E, by which the objects on the circle Fig 7, that is put at the bottom of the box, are seen at D. There is a magnetic bar concealed in the table, on which
the

the box is placed, that moves the circle Fig. 7, by the needle in the middle of it.

Fig. 5. Is a column placed on the middle of the box, and in which the spectators seem to see the objects shown by the perspectives.

P L A T E IX. p. 112.

Fig. 2. The box for the animated optic balls. IM the inclined plane, down which the ball O runs, and through the groove P, to the hole at the end of the box. K F is the mirror that reflects the inclined plane and the paintings in the box to the glass at E, and which is represented by Fig. 1. T the inclined plane for a double reflection. Fig. 4, 5, and 6, the machinery that raises the ball to the top of the inclined plane.

Fig. 3. The painting on the inclined plane.

P L A T E X. p. 118.

Fig. 1. The penetrating perspective. F and G are two moveable tubes. O, P, Q, R, are four inclined mirrors, that reflect the objects, entering the tube G, to the eye at F.

Fig. 2. The enchanted mirrors. A D and C B the two mirrors placed cross the box in a diagonal.

H and

H and L, two of the glaffes by which the spectators see each other.

Fig. 4. The machine for seeing an irregular figure in a multiplying glafs (Fig. 3.) A B the stand with the glafs fixed to it; H the hole through which the image is seen. Fig. 5, the ruler for drawing the reflection on the board D E F G. Fig. 6, 7, and 8, projections of the glafs.

P L A T E XI. p. 126.

Fig. 1. The cylindric mirror for viewing an irregular figure drawn on the board F G, from the point of view E, where it appears regular.

Fig. 2. The method of dividing the diameter of a circle into a number of parts, which are to be transferred to the cylinder, and reflected on the board, for tracing the irregular figure.

Fig. 3. The plan for drawing the regular figure.

Fig. 4, 5, and 6. The appearances of a bottle of water before a concave mirror.

P L A T E XII. p. 134.

Fig. 1. The perspective mirror. H the concave mirror, I L the blacked pasteboard for regulating the view, G the aperture for viewing the objects placed beneath it, in the mirror.

Fig. 2. A and B two concave mirrors for firing combustible bodies at a distance. C. and D their foci, in which the bodies are placed.

Fig.

Fig. 3. The machinery for the real apparition. C an inverted object placed under the hole in the partition AB, and which, by the reflection of the concave mirror, appears erect at D, on the outside of the partition.

P L A T E XII. p. 160.

Fig. 1. The ray of light LI, passing through the window shutter AB, is refracted by the prism DEF, into the Spectrum PQ, that exhibits all the seven primary colours.

Fig. 2, and 3. The glasses and painted papers for representing the several colours and their gradations.

Fig. 4. The magical prism. ABC a large prism, by which a ray of light is refracted, and falls on the small prism DEF, that, as it revolves on its axis, appears of different colours.

Fig. 5. The prismatic camera obscura. Ff two rays of light that being refracted by the prisms A, B, C, and a, b, c, form the spectrum MN, which appears to be painted with all the original colours.

P L A T E XIV. p. 166.

Fig. 1. A ray of light largely refracted into the spectrum PT, the divisions of whose colours correspond to the divisions of a chord for the notes of the octave.

Fig. 2, and 3. The machine for exhibiting colorific

lorific music. The shaded parts in fig. 2, represent the colours. F is the screw on which it turns, G a wheel that is moved by the endless screw H.

Fig. 3. Is the case that contains the cylinder. The eight shaded parts in the middle are the holes through which the colours on the cylinder are seen; O the handle that turns the endless screw.

P L A T E XV. p. 174.

Fig. 1, 2, and 3, The plans for drawing an irregular figure that will appear regular when seen through a hole in the stand Fig. 4, placed in the proper position.

P L A T E XVI. p. 180.

Fig. 1, 2, and 3. The plans for drawing an irregular figure, which when seen from two opposite points of view, presents two regular figures.

Fig. 4. A pasteboard in which lines are cut, and over them the paper Fig. 5, that contains the drawing that is to be pasted.

P L A T E XVII. p. 190.

Fig. 1, and 2. The apparatus for drawing an irregular figure on the base of a cone, that appears regular from the point H; FEG the cone; MN the position of a glass on which the regular figure is drawn, and that is projected on the cone
by

by the lamp Fig. 2, when placed in the room of the stand H I.

Fig. 3. The machine for drawing any object correctly. E A C the tube for viewing the object; BFDG the frame, shown more clearly in Fig. 4, by which the parts of the object are transferred to similar divisions on a paper.

Fig. 5. The box for illuminated prospects. EFGH the back of the box in which the prints are placed, and behind them lamps or candles.

P L A T E XVIII. p. 222.

Fig. 1. Shows the alternate vibrations of a chord.

Fig. 2. A chord so divided as to sound the seven concords.

Fig. 3. The apparatus for the ventrosal symphony. A B the vane that gives motion to the machine; C, D, G, H, I, M, wheels and pinions that serve to move the barrel N O, in which are a number of stops, that strike a set of bells.

Fig. 4. The whispering gallery. A the point from whence the sound proceeds, and is reverberated by the points D E F G, to C, where it is plainly heard.

Fig. 5. The converse statue. A B and G H are two concave mirrors; C and I their focusses; E F a partition that has a hole, through which a sound issuing at I, is distinctly heard at C.

P L A T E XIX. p. 240.

Fig. 1. Shows the mechanism of the great organ. O, O, are the handles that push down the bellows,

T T:

TT: *l, l*, are the handles that turn the rollers R, R, that by means of the arms *c, f*, pull out the sliders *b, g*, and give liberty to the pipes placed over any row of the holes to sound; C, D, E, &c. are the keys, which being put down open the valves V, that admit the air to the pipes: KKK is the wind-chest, that receives the air by the port-vent 4. X is a flute-pipe of wood; Y a trumpet-pipe of metal; Z a flute pipe of metal.

Fig. 2. Shows the construction of a valve, with the wire that opens it and the spring that shuts it.

Fig. 3. The inside of a flute pipe. A B the foot, B D the body; E F the partition; B C the mouth.

Fig. 4. A reed pipe; A B the foot: C D the shallot or reed; K L a plate of copper fitted into the mold at I, but being loose at its extremity K, the air makes it shake against the reed.

RATIONAL.



RATIONAL RECREATIONS.

O P T I C S.

THE science of optics explains the nature of vision, by investigating the causes of the various phenomena that arise from the refraction and reflection of light. It is divided into Dioptrics, Catoptrics, and Chromatics*. The first treats of refraction; the second, of reflection; and the last, of colours.

GENERAL DEFINITIONS.

I. When the rays of light that issue from any body, continually recede from

* These terms are derived from the Greek; the first from the word *dioptra*, a perspective glass; the second from *katoptron*, a mirror; and the last from *chromata*, colours.

each other, as the rays AB and AC (Plate I. Fig. 1.) they are said to diverge.

2. When rays in their progress draw continually nearer to each other, as the rays BF and CF, (Plate I. Fig. 1.) they are said to converge.

3. That point in which converging rays all meet, is called their focus; as the point F, in the same figure.

4. An optic angle is the space contained between two lines drawn from the extremities of any object to the eye. Thus AEB or CED (Plate I. Fig. 2.) are the optic angles under which the objects AB and CD appear to the eye at E.

GENERAL APHORISMS.

1. The motion of light is not instantaneous but progressive*.
2. All rays of light naturally proceed in right lines.
3. No object can be seen distinctly at a less distance than about eight inches.
4. To produce distinct vision, the rays of light must be parallel when they enter the eye, and the object well illumined.
5. Rays of light that come from a far distant object, are to be considered as parallel.
6. Wherever the rays that come from all the points of an object, meet again in

* It appears, by astronomical observations, that the rays of light are 8 minutes and 13 seconds in coming from the sun to the earth, which is distant about 82 millions of miles; their progress, therefore, is at the rate of about ten millions of miles in a minute; yet great as that velocity is, the distance of the nearest of the fixed stars being four hundred thousand times greater than that of the sun, the light must be more than six years in coming from them to us.

so many points, after they have been made to converge by refraction or reflection, they will there form an image of that object on any white body.

7. Every object seen by refraction or reflection, appears to be in that point from whence its rays are last refracted or reflected to the eye.

8. The apparent magnitude of any object is determined by the magnitude of its optic angle : therefore the objects A B and C D, (Plate I. Fig. 2.) which are seen under the same angle, will appear of equal magnitude.

These, and every other aphorism in this part, are confirmed by all optical writers ; and may be demonstrated geometrically : but as we suppose our readers to have no other previous knowledge than that of common arithmetic, it would be superfluous to insert such demonstrations here.

D I O P T R I C S.

DIOPTRICS, as we have said, explain the several appearances that arise from the refraction of light.

D E F I N I T I O N S.

1. When a ray of light passing out of one medium into another of a different density, is turned from that straight line in which it would otherwise proceed, into one of a different direction, it is said to be refracted. Thus the ray AB, (Plate I. Fig. 3.) by passing out of air into the glass GH, is turned from its natural course into that of CD.

2. Any spherical transparent glass that converges or diverges the rays of light as they pass through it, is called a lens.

3. Of lenses there are five sorts: 1. A plane or single convex lens, which is plane on one side, and convex on the other, as A (Plate I. Fig. 4.) 2. A double convex lens, as B. 3. A plano-concave lens,

B 3

that

that is plane on one side and concave on the other, as C. 4. A double concave, as D. And, 5. A meniscus, which is convex on one side and concave on the other, as E.

4. The point C, round which the spherical surface of a lens, as A Z (Plate I. Fig. 4.) is described, is called its center: the line X Y, drawn from that center perpendicular to its two surfaces, is the axis; and the point V, to which the axis is drawn, is the vertex of that lens.

5. When the rays of light that pass through a single or double convex lens are brought into their smallest compass, that point is the focus of the lens.

6. In optical instruments that lens which is next the object is called the object-glass; and that next the eye, the eye-glass.

7. The distance between the line A B (Plate I. Fig. 3.) and the perpendicular E B, is called the angle of incidence; and the distance between the line C D and the perpendicular B F, is called the angle of refraction.

APHORISMS.

1. A ray of light passing obliquely out of one medium into another that is denser, will be refracted toward the perpendicular, as the ray AB (Plate I. Fig. 3.) by passing out of air into glass is refracted into CD, toward the perpendicular BF. On the contrary, a ray passing out of a denser into a rarer medium, will be refracted from the perpendicular; as the ray CD, passing out of glass into air, is refracted into DI.

2. The angles of incidence, and refraction, when the lines that contain them are all equal, will have a determinate proportion to each other, in the same mediums: which between air and water will be as 4 to 3; between air and glass, as 3 to 2, nearly; and in other mediums in proportion to their densities.

3. When an object is viewed through a glass whose two surfaces are parallel, it will appear of its natural dimensions, its situation only being a small matter altered

in proportion to the thickness of the glass, and the obliquity of the rays.

4. All the rays of light, whether diverging, parallel, or converging, that fall on a single or double convex lens, will meet in a focus behind the glass; and the distance of that focus will be greatest in diverging, and least in converging rays.

5. When parallel or converging rays, fall on a single or double concave lens, they will diverge behind it. If they be diverging at their incidence, they will become more so by passing through it.

6. When an object is viewed through two convex lenses, its apparent length, or diameter, will be to its real length, as the distance of the focus of the object-glass, is to that of the eye-glass.

By these, and the foregoing aphorisms, we are enabled to account for the various effects of dioptric machines, as refracting telescopes, microscopes, the camera obscura, &c. For example, suppose AB the object glass, and CD the eye-glass of
a te-

Fig. 1. p 2.

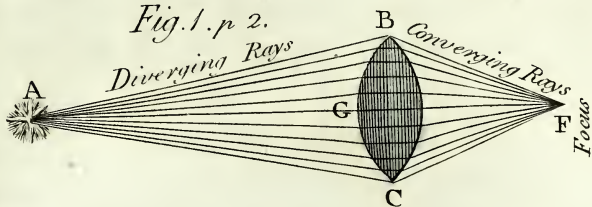


Fig. 2. p 2.

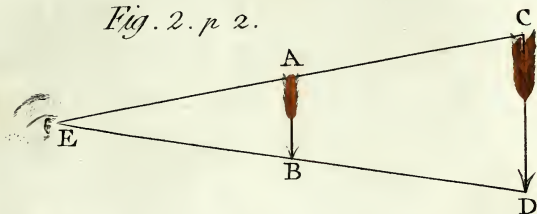


Fig. 3. p 5.

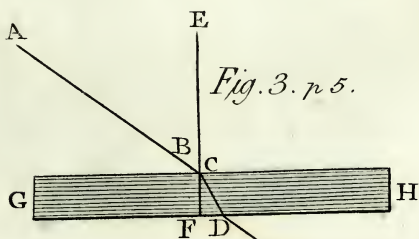
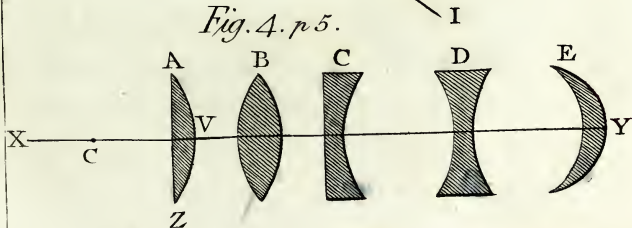
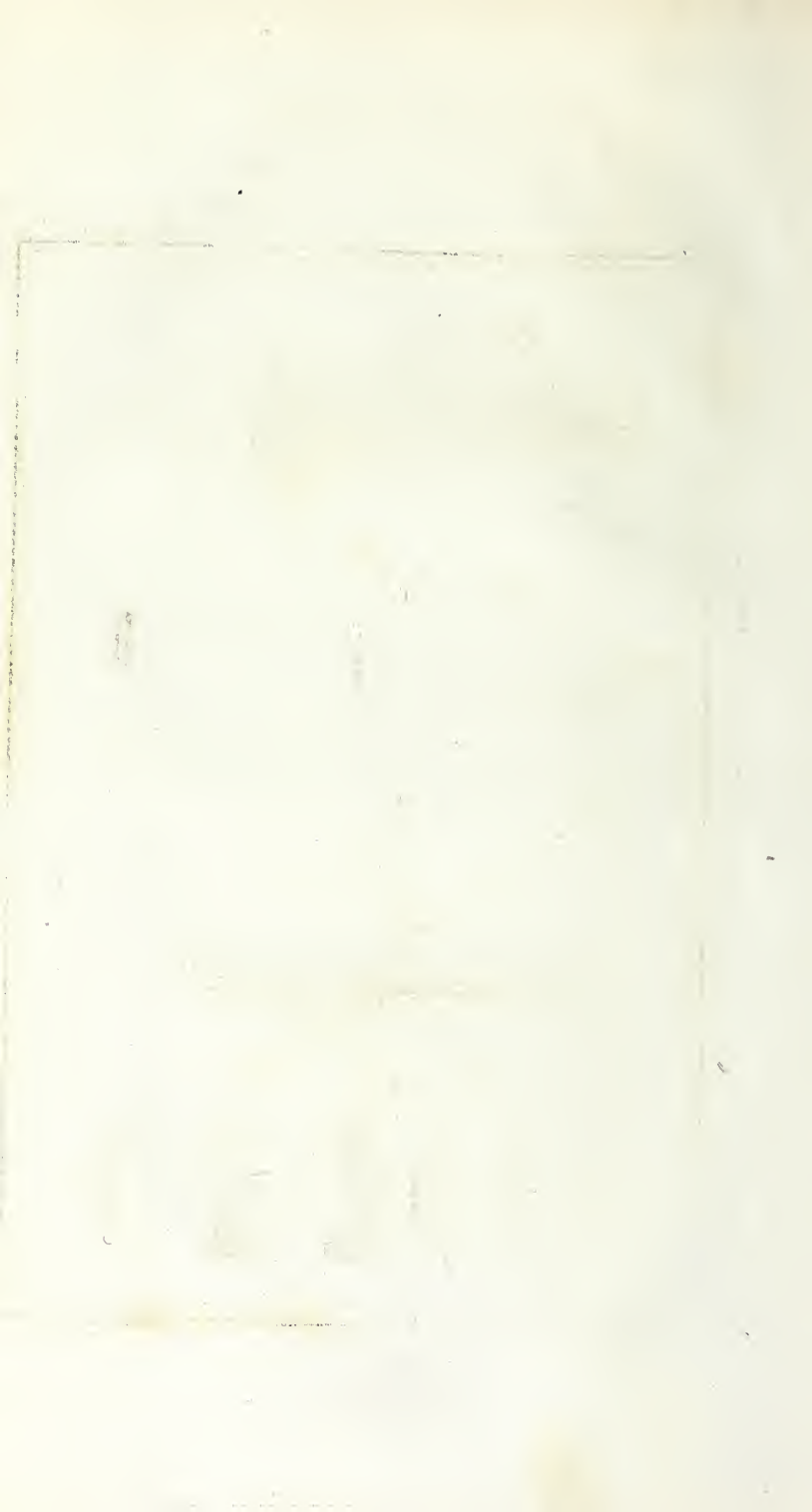


Fig. 4. p 5.





a telescope, (Plate II. Fig. 1.) and let them be so placed that the focus of each may coincide in the point E. Suppose OI to be a far distant object, whose rays are therefore to be considered as parallel when they come to the glass, (aphorism 5. page 3.) the two rays OA, and IB, proceeding from the extremities of the object, and passing through the glass A B, will meet and intersect each other in its focus E, and pass on to the eye-glass CD. But E being also the focus of that glass, those rays, by passing it, will again become parallel, and therefore by (aphorism 4. p. 3.) produce distinct vision in the eye, placed at H.

Now suppose the distance between A B and E, that is the focal length of the object-glass, to be ten feet, or 120 inches, and the distance between E and CD, which is the focal length of the eye-glass, to be three inches, then, by aphorism 6. p. 8. the apparent length or diameter of the object will be to its real length as 120 to 3,
or

or as 40 to 1, that is, its length will be magnified 40 times, and consequently its surface, if it be a square, 1600 times.

It is evident, from the construction of this telescope, that the object must appear to the eye inverted, but as it is principally intended for viewing celestial objects, that circumstance is not much regarded. But when it is applied to terrestrial views, two other glasses are added. One of which as E F, (Plate II. Fig. 2.) is placed at twice its focal distance from CD, and the other, G H, at the same distance from that. Now the rays being made to intersect each other again, as is evident from the figure, the object will then appear in its natural position.

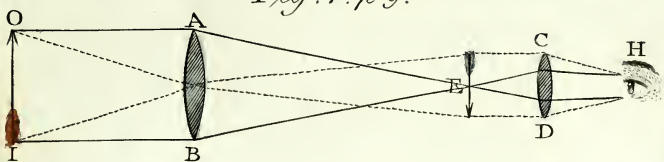
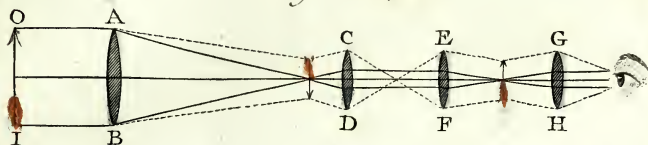
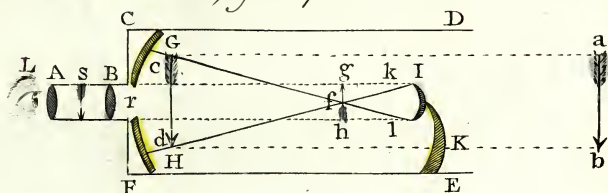
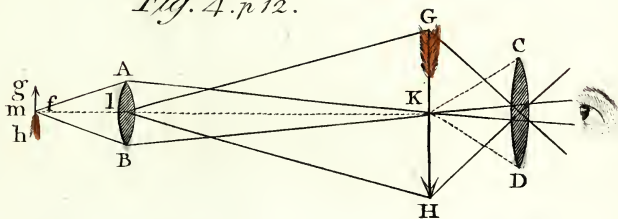
Terrestrial telescopes are sometimes made with one object-glass, and one concave eye-glass ; but as only a small part of an object can be seen by these at one view, they are of little use, except in near or large objects.

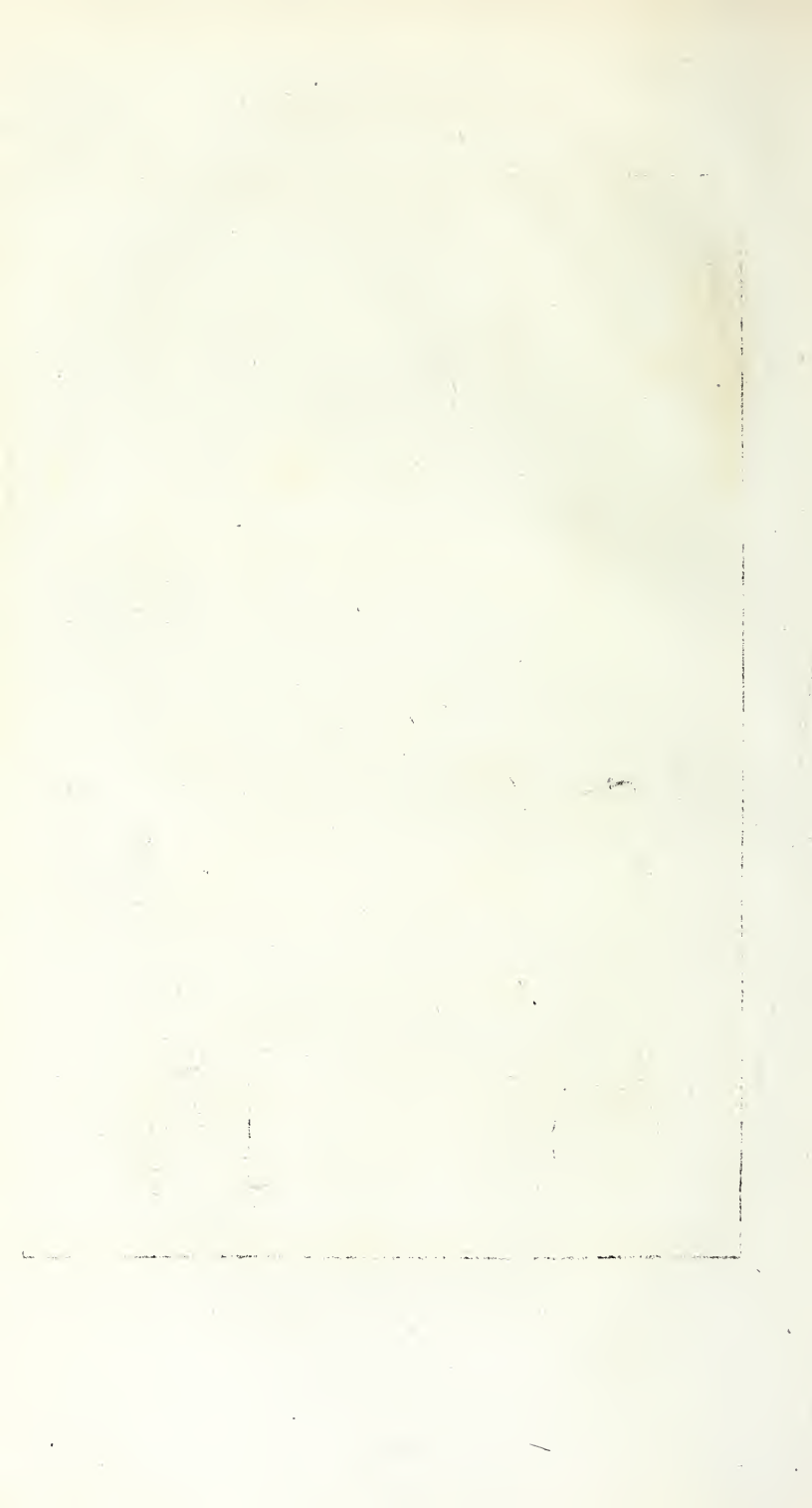
In

In like manner suppose *ABCDEF* (Plate II. Fig. 3.) to be the tube of a reflecting telescope, the end *DE* of which is open: let *GH* be a large concave metalline mirror, perforated at *r*. *I*, a smaller mirror, placed on the stand *K*. These mirrors are to be so disposed that the focus of each may fall on the point *f*. Now the image of an object, as *ab*, entering the tube at *DE*, will fall upon the mirror *GH* in the points *cd*, and being reflected from thence to the focus *f*, the rays will there intersect each other, and invert the image at *gh*. This image being also in the focus of the mirror *I*, after falling on it in the points *kl*, will be reflected back in parallel rays, which passing through the hole *r* in the great mirror, and falling on the convex lens at *B*, will again cross each other in the focus of that glass at *s*, which being also the focus of the lens at *A*, it will from thence be viewed by the eye at *L*. The principal excellence of reflecting telescopes arises from the brightness of
the

the reflection, by which objects appear so distinct that an eye-glass of a much smaller focus can be used in them than in others. The magnifying power in this, as in other telescopes, is as the focal distance of the object-glass or mirror, to the focal distance of the eye-glass. But the latter being so much smaller in this telescope, the magnifying power will be so much greater. Therefore, if the focal distance of the eye-glass be one inch, and that of the object mirror 40 inches, the diameter of the object will be magnified 40 times, and its surface 1600 times. A reflecting telescope of 4 feet will magnify more than a refractor of 50 feet.

Suppose, again, AB (Plate II. Fig. 4.) to be the object-glass, and CD the eye-glass of a double microscope. The object-glass must here be quite small and very convex, and consequently its focal distance lf , very short. The distance of the small object gmh , must be very little
more

Fig. 1. p 9.*Fig. 2 . p 10.**Fig. 3. p 11.**Fig. 4. p 12.*



more than that of lf , in order that its image GH , may be formed at a considerable distance, and consequently be much enlarged. Now this image will appear distinct and considerably magnified, and that on two accounts : first, in proportion as the distance Kl is greater than lm ; and secondly, on account of the nearness of the eye to the image ; for by aphorism 3. page 3. no object can be seen distinctly by the naked eye, at a less distance than eight inches, therefore if by means of the eye-glass CD , the object is made to appear distinct at the distance of one inch, it will seem eight times as large. Supposing, therefore, the focal distance of the eye-glass CD , to be one inch, and the distance Kl to be to lm as ten to 1, then, on both these accounts, the length of the object will appear 8 times 10, or 80 times, and it, surface 6400 times, larger than when seen by the naked eye.

RECRE-

R E C R E A T I O N I.

Optical illusions.

ON the bottom of the vessel A B C D, (Plate III. Fig. 1.) place three pieces of money, as a shilling, a half-crown, and crown ; the first at E, the second at F, and the last at G. Then place a person at H, where he can see no farther into the vessel than I : and tell him that by pouring water into the vessel you will make him see three different pieces of money ; bidding him observe carefully whether any money goes in with the water*.

When the water comes up to K, the piece at E will become visible ; when it comes up to L, the pieces at E and F will appear ; and when it rises to M, all the three pieces will be visible.

* You must either pour it in very gently, or contrive to fix the pieces, that they may not move out of their places by the motion of the water.

From

From what has been said of the refraction of light, the cause of this phenomenon will be evident : for while the vessel is empty, the ray H I will naturally proceed in a straight line : but in proportion as it becomes immersed in water, it will be necessarily refracted into the several directions NE, OF, PG, and consequently the several pieces must become visible.

RECREATION II.

Optical augmentation.

TAKE a large drinking glass of a conical figure, that is, small at bottom and wide at top ; in which put a shilling, and fill the glass about half full with water : then place a plate on the top of it, and turn it quickly over, that the water may not get out. You will then see on the plate, a piece of the size of a half crown ; and somewhat higher up, another piece of the size of a shilling.

This

This phenomenon arises from seeing the piece through the conical surface of the water at the side of the glass, and through the flat surface at the top of the water, at the same time: for the conical surface dilates the rays and makes the piece appear larger; but by the flat surface the rays are only refracted, by which the piece is seen higher up in the glass, but still of its natural size. That this is the cause will be farther evident by filling the glass with water, for as the shilling cannot be then seen from the top, the large piece only will be visible.

After you have amused yourself with this remarkable phenomenon, you may give the glass to a servant, telling him to throw out the water, and take care of the two pieces of money; and if he have no suspicion of the deception, he will be not a little surprised to find one piece only.

R E C R E-

RECREATION III.

Optical subtraction.

A GAINST the wainscot of a room fix three small pieces of paper, as A, B, C, (Pl. III. Fig. 2.) at the height of your eye; and placing yourself directly before them, at a few yards distance, shut your right eye and look at them with the left; when you will see only two of those papers, suppose A and B; but altering the position of your eye you will then see the third and one of the first, suppose A; and by altering your position a second time, you will see B and C; but never all three of them together.

The cause of this phenomenon is, that one of the three pencils of rays that come from these objects, falls on the optic nerve at D; whereas to produce distinct vision it is necessary that the rays of light fall on some part of the retina E, F, G, H. We

We see by this experiment, one of the uses of having two eyes ; for he that has one only, can never see three objects placed in this position, nor all the parts of one object of the same extent, without altering the situation of his eye.

R E C R E A T I O N XI.

Alternate illusion.

WITH a convex lens of about an inch focus, look attentively at a silver seal, on which a cypher is engraved. it will at first appear cut in, as to the naked eye ; but if you continue to observe it some time, without changing your situation, it will seem to be in relief, and the lights and shades will appear the same as they did before. If you regard it with the same attention still longer, it will again appear to be engraved : and so on alternately.

If you look off the seal for a few moments, when you view it again, instead

stead of seeing it, as at first, engraved, it will appear in relief.

If, while you are turned toward the light, you suddenly incline the seal, while you continue to regard it, those parts that seemed to be engraved, will immediately appear in relief: and if, when you are regarding these seeming prominent parts, you turn yourself so that the light may fall on the right hand, you will see the shadows on the same side from whence the light comes, which will appear not a little extraordinary. In like manner the shadows will appear on the left, if the light fall on that side. If instead of a seal you look at a piece of money, these alterations will not be visible, in whatever situation you place yourself*.

* It has been suspected that this illusion arises from the situation of the light; and in fact I have observed (says M. Guyot, from whom this article is taken) that when I have viewed it with a candle on the right, it has appeared engraved, but by changing the
light

[RECREATION V.]

The camera obscura, or dark chamber.

WE shall here give a short description of this optical invention; for though it is very common, it is also very pleasing, and though almost every one has seen it, every one knows not how to construct it.

light to the left side, it has immediately appeared in relief. It still, however, remains to be explained, why we see it alternately hollow and prominent, without changing either the situation or the light. Perhaps it is in the sight itself that we must look for the cause of this phenomenon; and this seems the more probable, as all these appearances are not discernible by all persons.

A phenomenon like this will appear to a superficial observer a very trifling matter: but the philosopher, who is desirous of explaining all the appearances of nature, will find it attended with no trifling difficulties. It is, moreover, by investigating the causes of phenomena seemingly insignificant, that the most important discoveries are sometimes made.

Make

Make a circular hole in the shutter of a window, from whence there is a prospect of the fields, or any other object not too near; and in this hole place a convex glass, either double or single, whose focus is at the distance of five or six feet*. Take care that no light enter the room but by this glass: at a distance from it, equal to that of its focus, place a pasteboard, covered with the whitest paper †; let it be two feet and a half long, and eighteen or twenty inches high: bend the length of it inwards, to the form of part of a circle, whose diameter is equal to double the focal distance of the glass. Then fix it on a

* The distance should not be less than three feet; for if it be, the images will be too small, and there will not be sufficient room for the spectators to stand conveniently. On the other hand the focus should never be more than 15 or 20 feet, for then the images will be obscure, and the colouring faint. The best distance is from 6 to twelve feet.

† This paper should have a black border, to prevent any of the side rays from disturbing the picture.

frame of the same figure, and put it on a moveable foot, that it may be easily fixed at that exact distance from the glass where the objects paint themselves to the greatest perfection. When it is thus placed, all the objects that are in the front of the window will be painted on the paper, in an inverted position *, with the greatest regularity and in the most natural colours.

If you place a moveable mirror without the window, by turning it more or less,

* This inverted position of the images may be deemed an imperfection, but it is easily remedied : for if you stand above the board on which they are received, and look down on it, they will appear in their natural position : or if you stand before it, and placing a common mirror against your breast in an oblique direction, look down in it, you will there see the images erect, and they will receive an additional lustre from the reflection of the glass ; or place two lenses, in a tube that draws out ; or, lastly, if you place a large concave mirror at a proper distance before the picture, it will appear before the mirror, in the air, and in an erect position.

you

you will have on the paper all the objects that are on each side of the window*.

If instead of placing the mirror without the window you place it in the room, and above the hole (which must then be made near the top of the shutter), you may receive the representation on a paper placed horizontally on a table ; and draw at your leisure, all the objects that are there painted.

Nothing can be more pleasing than this Recreation, especially when the objects are strongly enlightened by the sun : and

* There is another method of making the dark chamber, which is by a scioptric ball, that is, a ball of wood, through which a hole is made, in which hole a lens is fixed : this ball is placed in a wooden frame, in which it turns freely round. The frame is fixed to the hole in the shutter, and the ball, by turning about, answers, in great part, the use of the mirror on the outside of the window. If the hole in the window be no bigger than a pea, the objects will be represented without any lens.

not only land prospects, but a sea-port, when the water is somewhat agitated, or at the setting of the sun, presents a very delightful appearance.

This representation affords the most perfect model for painters, as well for the tone of colours, as that degradation of shades, occasioned by the interposition of the air, which has been so justly expressed by some modern painters.

It is necessary that the paper have a circular form, for otherwise, when the center of it was in the focus of the glass, the two sides would be beyond it, and consequently the images would be confused. If the frame were contrived of a spherical figure, and the glass were in its center, the representation would be still more accurate. If the object without be at the distance of twice the focal length of the glass, the image in the room will be of the same magnitude with the object.

The

The lights, shades, and colours in the camera obscura appear not only just, but, by the images being reduced to a smaller compass, much stronger than in nature: add to this, that these pictures exceed all others by representing the motion of the several objects: thus we see the animals walk, run, or fly, the clouds float in the air, the leaves quiver, the waves roll, &c. and all in strict conformity to the laws of nature. The best situation for a dark chamber is directly north, and the best time of the day is noon.

RECREATION VI.

To shew the spots on the sun's disk, by its image in the camera obscura.

PUT the object-glass of a ten or twelve foot telescope into the scioptric ball and turn it about till it be directly opposite the sun *. Then place the pasteboard, mentioned

* When the sun is directly opposite the hole the lens will itself be sufficient: or by means of the

mentioned in the last Recreation, in the focus of the lens, and you will see a clear bright image of the sun, of about an inch diameter, in which the spots on the sun's surface will be exactly described.

As this image is too bright to be seen with pleasure by the naked eye, you may view it through a lens, whose focus is 6 or 8 inches distant, which at the same time that it prevents the light from being offensive, will, by magnifying both the image and the spots, make them appear to greater advantage.

the mirror on the outside of the window, as in the fifth Recreation, the lens will answer the purpose at any time.

R E C R E-

RECREATION VII.

To magnify small objects by means of the sun's rays let it into a dark chamber.

LET the rays of light that pass through the lens in the shutter be thrown on a large concave mirror, properly fixed in a frame. Then take a slip, or thin plate of glass, and sticking any small object on it, hold it in the incident rays, at a little more than the focal distance from the mirror, and you will see, on the opposite wall, amidst the reflected rays, the image of that object, very large, and extremely clear and bright. This experiment never fails to give the spectator the highest satisfaction.

RECRE-

R E C R E A T I O N VIII.

The portable camera obscura.

THE great pleasure produced by the camera obscura in the common form has excited several to render it more universally useful by making it portable; easily fixed on any spot, and adapted to every prospect. We shall not here examine the merits of the various sorts that have been invented, among which there are doubtless several highly ingenious; but content ourselves with describing one that may have some advantages not to be found in others.*.

Let ABCD (Pl. III. Fig. 3.) be a frame of wood, of two feet long and about twenty inches wide; let its four sides be two inches and a half thick, and firmly joined together. In a groove formed in this

* This sort of portable camera appears to be the invention of M. Guyot.

frame

frame place a plate of clear glafs, E*. To each of the corners of this frame join a leg, with a hinge, that it may turn up, under the table. To the under part of the frame join four pieces of light wood, as H, which muſt alſo have hinges to fold up; and obſerve that when they are let down, as in the figure, they muſt cloſely join, by means of hooks, it being quite neceſſary that no light enter the box †.

To that juſt deſcribed, there muſt be added a ſmaller box M, in which muſt be an inclined mirror N, and in one of its ſides a moveable tube O, five or fix inches long. This tube muſt be furniſhed with a convex glafs, the focus of which, by the reflection of the mirror, muſt reach the glafs E in the frame.

* If the upper ſide of the glafs were convex, it would be ſtill better.

† The inſide of the box may be lined with black cloth, to make it as dark as poſſible.

There

There must also be a covering of black stuff, in form of a tent, to place over the top of the frame, by means of four little poles that go into holes in the corners of it. There must be an opening to this tent on the side A B, by a curtain to be drawn up, and which you are to let down over you, when you place yourself under it; that no light may enter. The three other sides should hang down some inches over the frame.

This camera is, indeed, something more cumbersome than those that have been hitherto invented; and yet, if properly made, it will not weigh more than twenty to five-and-twenty pounds. On the other hand, it is much more convenient; for as the coloured rays of objects paint themselves on the bottom of the glass in the frame, you may draw them without having your hand between the rays and their image.

When

When you have placed the frame on a spot a little elevated, that nothing may intercept the rays from falling on the glass in the tube, you fix a sheet of transparent varnished paper on the glass in the frame, by means of wax at its corners. Then placing yourself under the curtain, you trace on the paper all the outlines of the objects there represented, and if you think fit, you may also mark the extent of the shadows. If you want only the outlines, you may lay a thin plate of glass on that in the frame, and trace the strokes with a pencil and carmine. After which you must dip a sheet of paper in water, without making it too wet, and spreading it lightly over that glass, you will have the impression of the design there drawn.

Note, By each of these methods you will have the objects either in their natural position, or reversed: which will be an advantage when the design is to be engraved, and you will have it then appear in the natural position.

In

In using this machine, you should make choice of those objects on which the sun then shines, as the appearances of the shadows adds greatly to the beauty of the design. There are, however, circumstances in which it is to be avoided, as when you would paint a rising or setting sun, &c.

R E C R E A T I O N IX.

The magic lantern.

THIS very remarkable machine, which is now known over all the world, caused great astonishment at its origin. It is still beheld with pleasing admiration, and the spectator very frequently contents himself with wondering at its effects, without endeavouring to investigate their cause. The invention of this ingenious illusion is attributed to the celebrated P. Kircher, who has published, on various sciences, works equally learned, curious, and entertaining.

The

The design of this machine is to represent at large, on a cloth or board, placed in the dark, the images of small objects, painted with transparent colours on plates of glass.

Its construction is as follows. Let ABCD (Pl. III. Fig. 4.) be a tin box, eight inches high, ten long, and six wide (or any other similar dimensions.) At the top must be a funnel E, of four inches in diameter, with a cover F, which, at the same time that it gives a passage to the smoke, prevents the light from coming out of the box.

On the side AC there is a door, by which is adjusted a concave mirror G, of metal or tin, and of five inches diameter; being part of a sphere whose diameter is eighteen inches, this mirror must be so disposed that it may be pushed forward or drawn back by means of the handle H, that enters

the tin tube I, which is foldered to the door.

In the middle of the box must be placed a low tin lamp K, which is to be moveable. It should have three or four lights, that must be at the height of the focus of the mirror G.

In the side BD, and opposite to the mirror, there must be an aperture of three inches wide and two inches and a half high, in which is to be fixed a convex glass L, of the same dimension*, whose focus must be from four inches and a half to five inches, so that the lamp may be

* I prefer this form for the glass (says M. Guyot) that the picture thrown upon the cloth may have the same form, which is much preferable to a circular aperture, through which the figures can never be completely seen but when they are at the center of the glass. It is surprising that this imperfection has been suffered to continue so long, when it is so easily remedied.

placed

placed both in its focus, and in that of the concave mirror.

On the same side place a piece of tin MN, of four inches and a half square, having an opening at the sides of about four inches and a half high, and a quarter of an inch wide. Through this opening or groove are to pass the glasses, on which are painted the figures that are to be seen on the cloth. In this tin piece, and opposite the glass L, let there be an aperture of three inches and a quarter long, and two inches and a quarter high, to which must be adjusted a tube O, of the same form, and six inches long. This tube is to be fixed into the piece MN. Another tube, six inches long, and moveable, must enter that just mentioned, in which must be placed two convex lenses, P and Q; that of P may have a focus of about three inches, and that of Q, which is to be placed at the extremity of the tube, one of ten or twelve inches. The distance

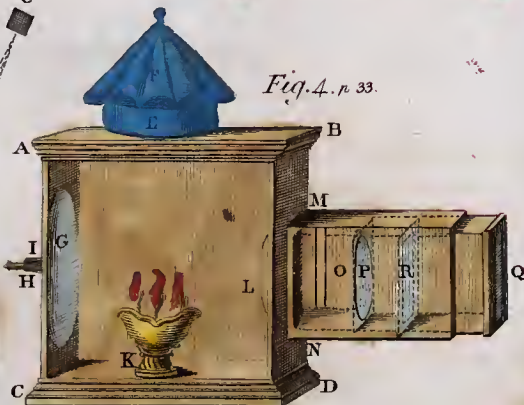
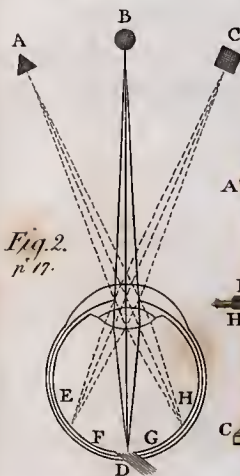
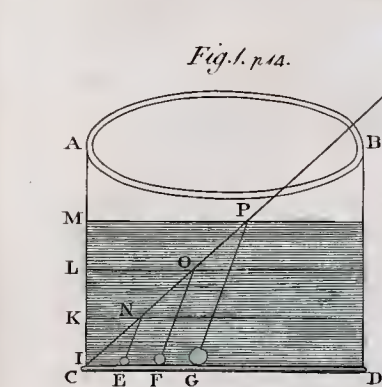
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between

between these glaffes is to be regulated by their foci. Between these glaffes there muſt be placed a paſteboard R, in which is an aperture of an inch wide, and 4-5ths of an inch high. By placing this tube farther in or out of the other, the images on the cloth will appear larger or ſmaller.

From what has been ſaid of the preceding machines, the conſtruction of this will be eaſily underſtood. The foci of the concave mirror, and the lens L, meeting in the flame of the lamp, they together throw a ſtrong light on the figures painted on the glaffes that paſs through the groove M N, and by that means render their colours diſtinct on the cloth. The rays from thoſe glaffes paſſing through the lens P are collected by the aperture in the paſteboard R, and conveyed to the lens Q, by which they are thrown on the cloth.

The lantern being thus adjusted, you muſt provide plates of clear glaſs, of twelve
or





or fifteen inches long, and three inches wide, which are to be placed in thin frames, that the may pass freely through the groove M N, after being painted in the manner we shall now describe.

Method of painting the glasses for the lantern.

Draw on a paper the subject you intend to paint, and fix it at each end to the glass. Provide a varnish with which you have mixed some black paint, and with a fine pencil draw on the other side of the glass, with very light touches, the design drawn on the paper. If you are desirous of making the painting as perfect as possible, you should draw some of the outlines in their proper colours, provided they are the strongest tints of those colours that are used. When the outlines are dry, you colour the figures with their proper tints or degradations; and those colours will not peel off, if you temper them with a

strong white varnish*, You are then to shade them with black mixed with the same varnish, or white bistre, as you find convenient. You may also leave strong lights in some parts, without any colours, in order to produce a more striking effect. Observe, in particular, not to use more than four or five colours, such as blue, red, green and yellow. You should employ however a great variety of tints, to give your painting a more natural air, without which they will represent vulgar objects, which are by no means the more pleasing because they are gaudy.

When the lamp in this lantern is lighted, and by drawing out the tube to a proper length, the figures painted on the glass appear bright and well defined, the spectator cannot fail of being highly enter-

* All those colours that are not terrestrial, as Prussian blue, carmine, calcined verdigris, &c. may be used to advantage, when tempered with a proper varnish.

tained by the fucceffion of natural or grotesque figures that are painted on the glaffes.

This piece of optics may be rendered much more amufing, and at the fame time more marvellous, by preparing figures to which different natural motions may be given*, which every one may perform according to his own tafte ; either by movements in the figures themfelves, or by painting the fubject on two glaffes, and paffing them at the fame time through the groove, as will be feen in the next Recreation.

* There are in the Philofophical Effays of M. Mufchenbroek, different methods of performing all thefe various movements, by fome mechanical contrivances that are not difficult to execute.

RECREATION X.

To represent a tempest, by the magic lantern.

PROVIDE two plates of glass, whose frames are so thin that they may both pass freely through the groove of the lantern at the same time.

On one of these glasses you are to paint the appearance of the sea, from the slightest agitation to the most violent commotion. Representing from A to B (Pl. IV. Fig. 1.) a calm; from B to C a small agitation, with some clouds; and so on to F and G, which should exhibit a furious storm. Observe that these representations are not to be distinct, but run into each other, that they may form a natural gradation; remember also, that great part of the effect depends on the perfection of the painting, and the picturesque appearance of the design.

On the other glass (Fig. 2.) you are to paint vessels of different forms and dimensions,

sions, and in different directions, together with the appearance of clouds in the tempestuous parts.

You are then to pass the glass (Fig. 1.) slowly through the groove, and when you come to that part where the storm begins, you are to move the glass gently up and down, which will give it the appearance of a sea that begins to be agitated ; and so increase the motion till you come to the height of the storm. At the same time you are to introduce the other glass with the ships, and moving that in like manner, you will have a natural representation of the sea and of ships in a calm and in a storm. As you draw the glasses slowly back, the tempest will seem to subside, the sky grow clear, and the ships glide gently over the waves.

This effect of the magic lantern must certainly afford more pleasure and surprise, than to see figures, frequently badly painted,

painted, appear one after the other in the midst of a luminous circle, as in a medal; whose form, besides being disgusting, prevents you from seeing any two figures, together, without the head and legs of one of them being entirely hid: an inconvenience that is avoided by this new method, even when you make use of the common figures.

By means of two glasses disposed in this manner you may likewise represent a battle, or sea fight, and numberless other subjects, that every one will contrive according to his own taste. They may be also made to represent some remarkable or ludicrous action between different persons, and many other amusements that a lively imagination will easily suggest. The instance we here give (says M. Guyot) being intended merely as an example, and to shew that this machine is capable of producing much more remarkable effects than have been hitherto exhibited.

R E C R E -

R E C R E A T I O N XI.

The nebulous magic lantern.

THE light of the magic lantern, and the colour of images, may not only be painted on a cloth, but also reflected by a cloud of smoke.

Provide a box of wood or pasteboard AB (Pl. IV. Fig. 3.) of about four feet high, and of seven or eight inches square at bottom, but diminishing as it ascends, so that its aperture at top is but six inches long, and half an inch wide. At the bottom of this box there must be a door that shuts quite close, by which you are to place in the box a chafing-dish with hot coals, on which is to be thrown incense, whose smoke goes out in a cloud at the top of the box. It is on this cloud that you are to throw the light that comes out of the lantern, and which you bring into a smaller compass by drawing out the moveable tube.

tube. The common figures will here serve. It is remarkable in this representation, that the motion of the smoke does not at all change the figures, which appear so conspicuous that the spectator thinks he can grasp them with his hand.

Note, In this experiment some of the rays passing through the smoke the representation will be much less vivid than on the cloth ; and if care be not taken to reduce the light to its smallest focus, it will be still more imperfect.

RECREATION XII.

To produce the appearance of a phantom, upon a pedestal placed on the middle of a table.

ENCLOSE a common small magic lantern in a box A B C D (Plate IV. Fig. 4,) that is large enough to contain also an inclined mirror M, which must be moveable, that it may reflect the
cone

cone of light thrown on it by the lantern, in such manner that it may pass out at the aperture made in the top of the box. There should be a flap with hinges to cover the opening, that the inside of the box may not be seen when the experiment is not making. This aperture should likewise be oval, and of a size adapted to the cone of light that is to pass through it.

There must be holes made in that part of the box which is over the lantern, to let out the smoke; and over that part must be placed a chafing-dish of an oblong figure, and large enough to hold several lighted coals*.

There must also be a glass that will ascend and descend at pleasure in the vertical groove *a b*. To this glass let there be

* This chafing-dish may be enclosed in a painted tin box of about a foot high, with an aperture at top something like Fig. 3. It should stand on four short feet, to give room for the smoke of the lamp to pass out.

fixed

fixed a cord, that, going over a pulley *c*, passes out of the box at the side *CD*, by which the glass may be drawn up, and will descend by its own weight.

On this glass may be painted a spectre, or any other more pleasing figure. Observe that the figures must be contracted in drawing, as the cloud of smoke does not cut the cone of light at right angles, and therefore the figures will appear longer than they do on the glass.

After you have lighted the lamp in the lantern, and put the mirror in a proper direction, you place the box or pedestal *ABCD* on a table, and putting the chafing-dish in it, throw some incense in powder on the coals. You then open a trap door, and let down the glass slowly; and when you perceive the smoke diminish you draw up the glass, that the figure may disappear, and shut the trap door. This appearance will occasion no small surprize, as the
spectre

ſpectre will ſeem to riſe gradually out of the pedestal, and on drawing up the glaſs will diſappear in an inſtant. Obſerve, that when you exhibit this Recreation you muſt put out all the lights in the room; and the box ſhould be placed on a high table, that the ſpectators may not perceive the aperture by which the light comes out. Tho' we have mentioned a ſmall magic lantern, yet the whole apparatus may be ſo enlarged, that the phantom may appear of a formidable ſize.

By having glaſſes properly painted, you may alſo produce the image of a flower, or a card, &c. like one you have burnt, and caſt the aſhes into the fire with the incenſe, and by that means pretend to make the image riſe out of the aſhes; with many other devices that every one may contrive of that kind which ſhall pleaſe him beſt.

R E C R E-

R E C R E A T I O N XIII.

The magical theatre.

BY making some few additions to the magic lantern with the square tube*, used in the ninth Recreation, various scenes, characters, and decorations of a theatre may be lively represented.

Let there be made a wooden box ABCD (Plate IV. Fig. 5.) a foot and a half long, fifteen inches high and ten wide. Let it be placed on a stand EF, that must go round it, and by which it may be fixed with two screws to a table. Place over it a tin cover, as in the common lantern.

Make an opening in its two narrowest sides; in one of which place the tube H,

* It is quite necessary to make the lantern much larger than common, that the objects painted on the glasses, being of a larger size, may be represented with greater precision, and consequently their several characters more strongly marked.

and

and in the other the tube I ; let each of them be six inches wide, and five inches high ; in each of these tubes place another that is moveable, in order to bring the glasses, or concave mirror, that are contained in them, to a proper distance ; as will be explained hereafter.

In the middle of the bottom of this box place a tin lamp, M, which must be moveable in a groove, that it may be placed at a proper distance with regard to the glasses and mirror : this lamp should have five or six lights, each of them about an inch long.

At the beginning of the tube H, toward the part N, make an opening of an inch wide, which must cross it laterally : another of three quarters of an inch, that must cross it vertically, and be nearer the box than the first ; and a third of half an inch, that must be before the first.

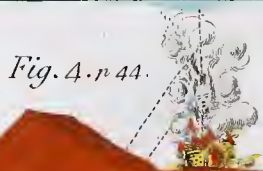
The opening made laterally must have three or four grooves, the second two, and

the third one : that different subjects of figures and decorations may be passed, either sideways, ascending, or descending, so that the scenes of a theatre may be the more exactly imitated*. Enclose these grooves between two convex rectangular glasses, of six inches long, and five inches high, and of about twenty inches focus ; one of which must be placed at O, and the other toward P. Have another tube Q, of about a foot long, which must enter that marked H ; and at its outward extremity place a lens of about fifteen inches focus.

There must also be a third tube R, four inches long, which is to enter that marked I : to the exterior end of this adjust a concave mirror, whose focus must be at seven or eight inches from its reflecting surface.

* In the decorations, the clouds and the palaces of the Gods should descend ; caves and infernal palaces should ascend ; earthly palaces, gardens, &c. enter at the sides.

This



[Redacted]

[Redacted]

[Redacted]

[Redacted]

[Redacted]

[Redacted]

[Redacted]

This magic lantern being thus adjusted, nothing more is necessary than to provide glasse, painted with such subjects as you would represent, according to the grooves they are to enter. The lamp is then to be lighted, and placing a glass in one of the grooves, you draw out the moveable tubes till the object paints itself on a cloth to the most advantage: by which you determine the distance of the lantern, and the size of the image. You then make a hole in the partition of that size, and fix in it a plate of clear glass, over which you paste a very thin paper, which must be varnished, that it it may be as transparent as possible.

It is on this paper that are to be exhibited the images of all those objects, that by passing successively through the grooves, are to represent a theatric entertainment. This exhibition will be the more agreeable, as the magic lantern being concealed behind the partition, the cause of the

E 2
illusion

illusion cannot by any means be discovered.

In order to show more clearly in what manner a subject of this sort should be painted, and the glasses disposed, we will here make choice of the siege of Troy, for a theatric subject; in which will be found all the incidents necessary to the exhibition of any other subject whatever.

In the first act, the theatre may represent, on one side the ramparts of Troy, toward the back part the Grecian camp, and at a farther distance, the sea and the isle of Tenedos. We will suppose the time to be that when the Greeks feigned to raise the siege, and embarked, leaving behind them the wooden horse, in which were contained the Grecian foldiers.

On a glass, therefore, of the same width with the aperture made in the side AC of the box, you are to paint a deep blue curtain,

tain, lightly charged with ornaments, quite tranſparent. This glaſs is to be placed in the firſt ventricle groove, ſo that by letting it gently down *, its image may appear to riſe in the ſame manner as the curtain of a theatre.

You muſt have ſeveral glaſſes of a proper ſize to paſs through the horizontal grooves, and of different lengths according to the extent of the ſubject. You may paint,

On the firſt the walls of Troy.

On the ſecond the Grecian camp.

On the third, the ſea, the iſle of Tenedos, and a ſerene ſky.

On the fourth, the Grecian troops, by detached figures.

On the fifth, other troops, diſpoſed in battalions, and placed at a diſtance.

* All the glaſſes that are to riſe and deſcend muſt be bordered with thin pieces of wood, and ſo exactly fill the grooves, that they may not ſlide down of themſelves.

On the fixth, divers veffels, which, as the glafs advances in the groove, diminifh in fize.

On the feventh the wooden horfe and Sinon.

On the eighth, Trojan men and women.

Thefe glaffes being properly painted *, you place in the horizontal grooves the firft, fecond, third, and fourth. Then draw up the curtain, by letting down the glafs on which it is painted, and draw away gently the fourth glafs, and after that the fecond ; then advance, very gently, the fifth, that represents the embarkment, and pafs it quite through. Next pafs, the oppofite way, the fixth, which represents the Grecian fleet. The objects painted on the fourth, fifth, and fixth quite difappearing, you are to advance the feventh, on which is painted the

* Unless you can procure glaffes well painted, it were better to represent fome comic fubject, where common paintings may fuffice.

wooden horse, and at the same time the eighth, where the Trojans will appear to draw the horse into the city. The curtain is then to be let down, that you may withdraw the scenes of the first act, and place in the grooves those that are to compose the second.

In the second act may be represented the interior part of the city of Troy : on one side may be seen the wooden horse, and in the back part the temple of Pallas. The glasses for this act may be painted in the following manner.

On the first may be palaces and houses, representing the inside of a city.

On the second, the temple of Pallas in the centre, with a clear night and the moon. In the front may be seen the wooden horse, that the Trojans have placed near the temple of Pallas.

On the third, a troop of Greeks, with Sinon at their head, who are going to

open the gates of the city to the Grecians.

On the fourth, different troops of armed Greeks ; painted on a long glass, to afford variety.

On the fifth, several troops of Trojans.

On the sixth, various appearances of fire and smoke, so disposed that this glass being drawn up above the others, the objects painted on the first glass, may appear in a conflagration.

Before you draw up the curtain you should place the first and second glasses. You then pass the whole third glass slowly a little after, the fourth, on which are painted the different bodies of armed Greeks, and at the same time, from the opposite side, the sixth glass, that represents the Trojan troops ; observing to move them slowly both in advancing and retreating, to imitate a combat *. Then

* He that moves the glasses, seeing the effect they produce, is the better able to render the representation as natural as possible.

draw up, by degrees, the fixth, on which are painted the fire, flame, and fmoke, fo that the palaces and houfes painted on the firft glafs, may appear to take fire gradually, and at laft prefent a general conflagration. After having represented thefe incidents with the greateft attention, you let fall the curtain to prepare for the third act.

In the third act may be represented the infide of Priam's palace, where is feen an altar, round which feveral Trojan princeffes appear, who have fled thither for fafety.

On the firft glafs may be painted the palace.

On the fecond, a view of the back part of the palace, with the altar.

On the third, Priam with feveral Trojan men and women.

On the fourth, Pyrrhus, and a troop of Greeks.

On the fifth, the fame actors, with the palace in flames.

On

On the fixth, A conflagration.

The two first glaffes which are to be drawn up, fhould be placed before you raife the curtain. Then pafs the third; next advance the fourth, which being drawn up, difcovers on the fifth the palace in flames, then drawing up the fixth, let down the firft, that the palace may appear entirely destroyed by the conflagration.

The fourth act may represent the environs of Troy, with a diftant profpect of the fea. The firft and third glaffes of the firft act may be here ufed, to which may be added a third, representing Eneas bearing his father Anchifes, followed by his fon Iulus, and fome Trojans. With this glafs may be represented the flight of the Trojans, and the embarkment of Eneas, with another glafs, on which are painted certain veffels.

To this act the following fcenes may be added. The cave of Æolus; the back
part

part of the cave; Æolus; the winds; Juno in her chariot.

The fifth act should represent the open sea, with the fleet of Eneas sailing for Italy.

On the first glass must be painted the sea, as in the tenth Recreation, or else the waves should be imitated by another glass under the first.

On the second, The Trojan fleet.

On the third, Neptune in his car.

On the fourth, the palace of Jupiter.

On the fifth, the inside of the palace; the Gods assembled in council, with Venus, obtaining leave of Jupiter for Eneas to land in Italy.

After having placed the first glass, that represents a calm sea, the curtain is raised, and the second scene is advanced, which contains the Trojan fleet. The first is then brought forward, to represent a violent

lent tempest: then raising the third glass, Neptune appears, who commands the waves to be still, which is done by making the tempest subside by degrees. The fleet then advances, and passes over the whole theatre: presently after the fourth and fifth scenes descend, that represent Olympus, and finish the exhibition.

Note. We must here repeat, that if you would represent a subject of this sort to advantage, it is quite necessary that the glasses be well painted: and those that are to be in front, should be in stronger and more opaque colours, that the images of those behind may not appear mixed with them, which will be the case if they are all equally transparent.

The glasses should also be of different lengths, that some being placed before the others are drawn away, their extremities may not be perceived.

The

The larger these subjects are represented the better effect they will have : the front of the theatre should appear to be about three feet wide : and, as we have said elsewhere, if some parts of the figures were moveable it would still add to the variety of the entertainment.

This and most of the other Recreations we have here given in the two first parts of Optics, appear to have been invented by M. Guyot, who has taken no small pains in the improvement of this sort of recreations.

C A T O P T R I C S.

CATOPTRICS is that part of optics which explains the properties of reflected light, and particularly that which is reflected from mirrors.

D E F I N I T I O N S.

1. Every polished body that reflects the rays of light is called a mirror, whether its surface be plane, spherical, conical, cylindric, or of any other form whatever.

2. Of mirrors there are three principally used in optical experiments, which are, the plane mirror, GHI, (Plate V. Fig. 1.) the spherical convex mirror, GHI, (Plate V. Fig. 2.) and the spherical concave mirror, GHI, (Plate V. Fig. 3.)

3. The point K, (Plate V. Fig. 2 and 3.) round which the reflecting surface of a spherical mirror is described, is called its centre. The line KH, drawn from its
center

center perpendicular to its two surfaces, is the axis of the mirror, and the point H, to which that line is drawn, is its vertex.

4. The distance between the lines A G and B G, (Plate V. Fig. 1.) is called the angle of incidence, and the distance between B G and C G is the angle of reflection.

A P H O R I S M S.

I. In a plane Mirror.

1. The image D F. (Plate V. Fi. 1.) will appear as far behind the mirror, as the object A C is before it.

2. The image will appear of the same size, and in the same position as the object.

3. Every such mirror will reflect the image of an object of twice its own length and breadth.

4. If the object be an opaque body, and its rays fall on the mirror nearly in direct lines, there will be only one image visible,
which

which will be reflected by the inner surface of the glafs. But

5. If the object be a luminous body, and its rays fall very obliquely on the mirror, there will appear to an eye placed in a proper position, several images; the first of which, reflected from the outer surface of the glafs, will not be so bright as the second, reflected from the inner surface. The following images, that are produced by repeated reflections of the rays between the two surfaces of the glafs, will be in proportion less vivid, to the eighth or tenth, which will be scarce visible.

II. In a Spherical Convex Mirror.

1. The image DF, (Plate V. Fig. 2.) will always appear behind it.

2. The image will be in the same position as the object.

3. It will be less than the object.

4. It will be curved, but not, as the mirror, spherical.

5. Parallel rays falling on this mirror will have the focus or image at half the distance

distance of the center K, from the mirror.

6. In converging rays, the distance of the object must be equal to half the distance of the center, to make the image appear behind the mirror.

7. Diverging rays will have their image at less than half the distance of the center. If the object be placed in the center of the mirror, its image will appear at one-eighth of that distance behind it.

III. In a Spherical Concave Mirror.

1. That point where the image appears of the same dimensions as the object, is the center of that mirror.

2. Parallel rays will have their focus at one half the distance of the center.

3. Converging rays will form an image before the mirror.

4. In diverging rays, if the object be at less than one half the distance of the center, the image will be behind the mirror, erect, curved, and magnified, as DEF (Plate V. Fig. 3.) but if the distance of the object be greater, the image will be before

the mirror, inverted and diminished, as DEF, (Plate V. Fig. 4.)

5. The sun's rays falling on a concave mirror, and being parallel, will be collected in a focus at half the distance of its center, where their heat will be augmented in proportion of the surface of the mirror to that of the focal spot.

6. If a luminous body be placed in the focus of a concave mirror, its rays being reflected in parallel lines, will strongly enlighten a space of the same dimension with the mirror, at a great distance. If the luminous object be placed nearer than the focus, its rays will diverge, and consequently enlighten a larger space*.

IV. In all plane and spherical mirrors the angle of incidence is equal to the angle of reflection†.

* It is on this principle that reverberators are constructed.

† This aphorism holds true of cylindric mirrors also, and of those whose surfaces are elliptical, parabolic, &c.

R E C R E-

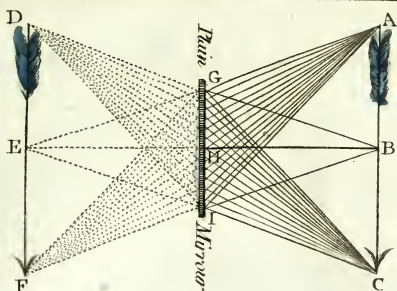


Fig. 1.
p 62.

Fig. 2.
p 62.

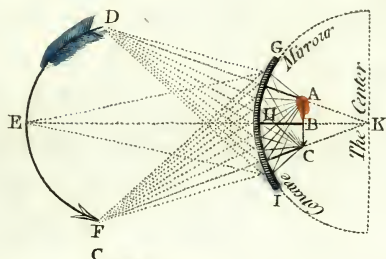
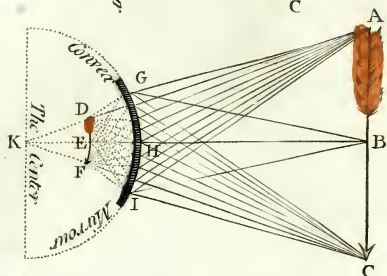
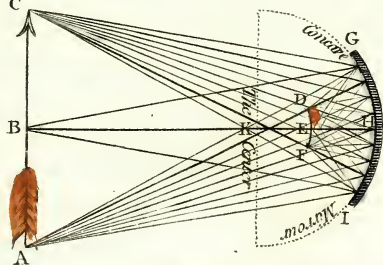


Fig. 3.
p 62.

Fig. 4.
p 66.





RECREATION XIV.

The boundless gallery.

CONSTRUCT a box AB, Plate VI. Fig. 1. of about a foot long, eight inches wide, and six high; or what other dimension you shall think fit, provided it does not greatly vary from these proportions.

On the inside of this box, and against each of its opposite ends A and B, place a mirror of the same size. Take off the quicksilver from the mirror that you place at B, for about an inch and an half, at the part C, where you are to make a hole in the box of the same size, by which you may easily view its inside. Cover the top of the box with a frame, in which must be placed a transparent glass, covered with gauze, on the side next the inner part of the box. Let there be two grooves at the parts E and F to receive the two painted scenes hereafter mentioned. On two pieces

F 2
of

of cut pasteboard let there be skilfully painted on both sides (see Fig. 2. and 3.) any subject you think proper ; as woods, gardens, bowers, colonades, &c. and on two other pasteboards, the same subjects on one side only ; observing that there ought to be in one of them some object relative to the subject placed at A, that the mirror placed on D may not reflect the hole at C on the opposite side.

Place the two boards painted on both sides (Fig. 2. and 3.) in the grooves E and F ; and those that are painted on one side only, against the opposite mirrors C and D ; and then cover the box with its transparent top. This box should be placed in a strong light to have a good effect.

When the eye is placed at C, and views the objects on the inside of the box, of which some, as we have said, are painted on both sides, they are successively reflected from one mirror to the other ; and if,
for

for example, the painting consists of trees, they will appear like a very long vista, of which the eye cannot discern the end: for each of the mirrors repeating the objects, continually more faintly, contribute greatly to augment the illusion.

RECREATION XV.

The four magical mirrors.

TAKE a square box ABCD, (Plate VI. Fig. 4.) of about six inches long, and twelve high*; cover the inside of it with four plane mirrors, which must be placed perpendicular to the bottom of the box CHFD.

Place certain objects in relief on the bottom of this box; suppose, for example, a piece of fortification, (as Fig. 5.) with tents, foldiers, &c. or any other subject

* We do not mean to limit the box to this size; any other may be used, provided, however, that it have nearly the same proportions.

that you judge will produce an agreeable effect by its disposition, when repeatedly reflected by the mirrors.

On the top of this box place a frame of glass, in form of the bottom part of a pyramid, whose base $A G E B$, is equal to the size of the box: its top $ILMN$, must form a square of six inches, and should not be more than four or five inches higher than the box. Cover the four sides of this frame with a gauze, that the inside may not be visible but at the top $ILMN$, which should be covered with a transparent glass.

When you look into this box through the glass $ILMN$, the mirrors that are diametrically opposite each other, mutually reflecting the figures enclosed, the eye beholds a boundless extent, completely covered with these objects; and if they are properly disposed, as in the example here given, in Fig. 5. the illusion will
occasion

Fig. 1. p 67.

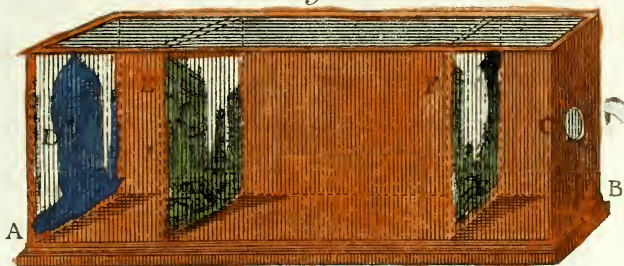


Fig. 2. p 68.

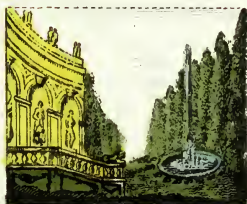


Fig. 3. p 68.

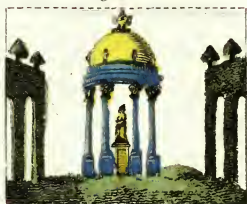


Fig. 5. p 70.

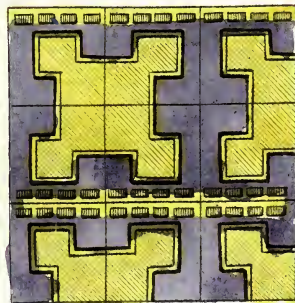
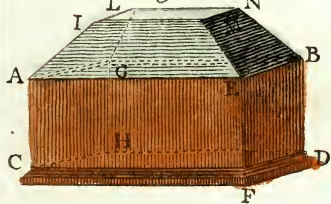


Fig. 4. p 69.



occasion no small surprize, and afford great entertainment.

Note, The nearer the opening ILMN is to the top of the box, the greater will be the apparent extent of the subject. The same will happen if the four mirrors placed on the sides of the box be more elevated. The objects, by either of these dispositions, will appear to be repeated nine, twenty-five, forty-nine times, &c. by taking always the square of the odd numbers of the arithmetic progression 3, 5, 7, 9, &c. as is very easy to conceive, if we remember that the subject enclosed in the box is always in the center of a square, composed of several others, equal to that which forms the bottom of the box.

Other pieces of the same kind (that is viewed from above) may be contrived, in which mirrors may be placed perpendicular on a triangular, pentagon, or
F 4 hexagon,

hexagon (that is, a three, five, or six-sided) plane. All these different dispositions, properly directed, as well with regard to the choice as position of the objects, will constantly produce very remarkable and pleasing illusions.

If instead of placing the mirrors perpendicular, they were to incline equally, so as to form part of a reversed pyramid, the subject placed in the box would then have the appearance of a very extensive globular or many-sided figure.

R E C R E A T I O N XVI.

The enchanted palace.

ON the hexagonal or six-sided plane ABCDEF (Pl. VII. Fig. 1.) draw six semi-diameters GA, GB, GC, GD, GE, GF, and on each of these place, perpendicularly, two plane mirrors, which must join

join exactly at the center G*. Decorate the exterior boundary of this piece (which is at the extremity of the angles of the hexagon) with six columns, that at the same time serve to support the mirrors, by grooves formed on their inner sides. (See the profile, Fig. 1.) Add to these columns their entablatures, and cover the edifice in such manner as you shall think proper.

In each one of these six triangular spaces, contained between two mirrors, place little figures of pasteboard, in relief, representing such objects as when seen in an hexagonal form will produce an agreeable effect. To these add small figures of enamel ; and take particular care to conceal, by some object that has relation to the subject, the place where the mirrors join, which, as we have said before, all meet in the common center G.

* These mirrors, placed back to back, must be as thin as possible.

When

When you look into any one of the fix openings of this magical palace, the objects there contained being repeated fix times, will seem entirely to fill up the whole of the building. This illusion will appear very remarkable; especially if the objects made choice of are properly adapted to the effect that is to be produced by the mirrors.

Note, if you place between two of these mirrors part of a fortification, as a curtain and two demi-bastions, you will see an entire citadel, with its fix bastions. Or if you place part of a ball room, ornamented with chandeliers and figures in enamel, all those objects being here multiplied will afford a very pleasing prospect.

RECREATION XVII.

To draw an irregular figure, which shall appear regular when viewed in a plane mirror

DIVIDE the square ABCD (Pl. VII. Fig. 2.) into such number of lesser squares as you shall think proper, and then draw on it the subject you would represent. Make the line GF (Fig. 3.) equal to a side of the square ABCD; and after having divided it into two equal parts at the point E, through that point draw the indefinite line AB, which must cut the line GF at right angles. Take any two points in the line AB, as A and B, equally distant from the point E, and draw from the point A the lines AC and AD, which you must continue till they meet the line CD, parallel to GF.

On the point A draw AH perpendicular to AB, and of an equal length with the
line

line CD , that is double of that which forms a side of the square $ABCD$.

Divide the line CD into as many equal parts as there are in a side of the square $ABCD$, and from the point A draw the lines Aa , Ab . From the point of view H , draw the line HD , which by cutting the lines Aa , AB , Ab , will show you the points of the section from which you are to draw the lines fg , parallel to GF and CD .

Then transpose on the trapezium, or irregular four-sided figure, $GFCD$ (which will be divided into as many perspective squares as there are natural squares in Fig. 1. $ABCD$) the design traced on that square; and on the line FG , place perpendicularly a mirror of an equal size with that square. The distorted figure traced on the trapezium $GFCD$ being then viewed in the mirror from a point elevated perpendicularly over the point B , to the height
of

of CD, will appear exactly similar to that traced on the square A B C D. It will appear equally regular if the mirror be taken away, and it be viewed from the point H.

Note, Before you colour the distorted figure drawn on the trapezium, you should paste it on a board of a parallelogram figure, whose sides are equal to the lines EB and CD : and fill up the space beyond the trapezium with such figures as you shall think proper, the better to disguise it : these extra figures will not appear in the mirror, if you have the precaution to raise at the point B a stand that shall bear a circle with a small hole, thro' which the object is to be seen in the mirror. This contrivance will considerably augment the illusion.

R E C R E A T I O N XVIII.

The magical dial.

PROCURE a dial-case as ABCD (Pl. VII. Fig. 4.) of the size of those that are commonly used to hold a watch. Let it be placed on a pedestal CDEF, in which there must be a small drawer H, that can hold the plate ABCD, (Fig. 5.) on which plate draw the circle of hours E, and in the center let there be a magnetic needle, placed on the point of an axis, which, passing through the plate, carries on its other point an artificial magnet, that must be concealed in the part under the plate*.

Place at the bottom of the dial case, at the part I, another dial, the hours of

* The magnetic needle itself may do, if it be not too far from the other dial. That this needle may not be suspected of having been touched it may be gilt, so as to appear like brass.

which

which are to be reverfed, as it is expreffed in Fig. 6. and whose hour of twelve muft be placed next the front of the cafe G. Adjust a pivot to the center of this plate, and fix on it a magnetic needle.

Cover the openings at the fides of the front of the dial-cafe (except where the dial appears) with a glafs lined with gauze on the infide, that the light may pafs in and illumine the dial that is there placed. Towards the top of the dial-cafe place an inclined mirror LM, which by reflecting the dial placed at the bottom of the cafe, will make it vifible at the part N, where you muft adjust a circle of pafteboard, that bordering the part where the dial appears, and being placed on the infide, will prevent the borders or the back part of the mirror from being feen.

Matters being thus adjusted, when the hand of the dial (Fig. 5.) is fet to any hour, and it is placed in the drawer, fo that the
hour

hour of twelve may be next the ring by which it is pulled out, the hand of the other dial, placed at the bottom of the case, will direct itself to the same hour; and by looking at the part N, you will see by the reflection of the mirror, the hour appear in the front of the dial plate.

Give the dial (Fig. 5.) to any one, and tell him to set the hand privately to any hour he please, and then place it in the drawer, only observing that the hour of twelve be next the ring, and he will then see that the hand of the dial at top will direct itself to the same hour.

Note, If attention be had to place the dial-case so on the table, that the hand of the dial which is concealed (and which will of itself turn towards the north, when the other dial is not under it) direct itself to the present hour when the experiment is making, it will appear the more extraordinary;



dinary; because, when the drawer is taken away, it will again turn to the present hour, which will render the cause of the illusion still more mysterious.

RECREATION XIX.

The box of divination.

LET a box be made with hinges, like ABCD (Pl. VIII. Fig. 1.) of about eight inches long, two wide, and half an inch thick; divide the inside of it into four equal parts, by small partitions. Have four small cases E, F, G, H, which will each of them fit any of the divisions, and in each of them you must fix a small artificial magnet, whose poles are to be placed as is expressed in the figure. Cover these cases with pasteboard or very thin ivory, on which you are to write any four figures you shall think fit.

To a table IL, whose wood is not too thick, fit a drawer, at the bottom of which

must be placed an inclined mirror MN, of the same length and breadth with the box just mentioned. Under the board that forms the top of the table, and toward the side where the drawer opens, place a small brass rod, turned up at its extremities, and on which there must be four pivots, at the same distance from each other as are the centers of the cases placed in the box. These pivots are to support four circles of pasteboard PQRS (Fig. 2, and 3.) which must each of them have a magnetic needle.

Observe, that the figures on the pasteboard must not only be reversed, but must be wrote on the under side, next the bottom of the drawers, that when it is opened they may be seen in the mirror there placed. Have regard also to the disposition of the poles of the needles, in the manner as is clearly expressed in the third figure.

Matters

Matters being thus prepared, when you have placed on the table the box and the four numbers there included, so that they may be exactly over the four circles of pasteboard concealed in the drawer, that is, that the centers of the one may be precisely over the centers of the other, the needles on the circles will conform themselves exactly to the magnets in the cases; so that if an instant after having placed the box, you open the drawer so far as to see the mirror, you will there perceive the number that the four figures on the cases make.

Then give the box and the four cases to any one, and tell him to form privately any number, by placing the cases in what order he shall think fit, and return you the box firmly closed. You then place it on the table over the circles, and opening the drawer, under pretence of taking out an opera-glass, you cast your eye on the mirror, and observe the order of the figures

there expressed. You then shut the drawer, and retiring to a distance, pretend to discern, by the opera-glass, the number you have observed.

R E C R E A T I O N XX.

The magical perspectives.

AT the bottom of an heptagonal or seven-sided box, as A B C D E F G (Pl. VIII. Fig. 4.) of about eight inches diameter and an inch and an half deep*. Place a circle of pasteboard, of five inches and a half diameter, very light and moveable, on a pivot fixed in the center H: on this circle fix a strongly magnetic needle I, and divide the circle into 21 equal parts, as is expressed in Fig. 7. The top of the box is to be covered with glass, over which you must paste a sheet of very fine paper, painted the same colour with the box, and

* This box should be so constructed as to appear to be the pedestal to the three perspectives hereafter described.

varnished, that the light may easily pass through it, and illumine the objects which are to be wrote or painted on the paste-board circle. On the middle of the top of this box erect a column I (see Fig. 5.) supported on a pedestal M, and crowned with its capital N.

In the glass that covers the box there must be three circular holes, at equal distances from each other, as O, P, Q, each of them three fourths of an inch in diameter, and on each must be fixed, immoveable, a perspective glass, like that in the sixth figure of this plate.

Construction of the perspective glass.

Provide a stand of wood A (Fig. 6.) in which a hole is made from top to bottom, of 3-4ths of an inch in diameter; on this stand place the perspective B C, which must have a second tube D, like the common glasses. In the larger part of it F,

G 3

there

there must be a smaller oval mirror E, which inclines or is elevated as the tube D is thrust in or drawn out. Let there be a circular hole at that part of the tube which rests on the stand A, that when the mirror is inclined, you may see through the stand of the perspective any object that shall be placed in the box, under one of the holes OPQ*. Let the three perspectives so constructed be placed, immoveable, over those three holes.

The combination of objects that may be drawn on the moveable circle in the box.

This circle is to be divided, as we have said, into 21 equal parts, and each of these divisions must appear under each of the openings O, P, Q, as the circle turns round on its pivot.

* At the bottom of the stand of each perspective there may be placed a lens of five or six inches in diameter, to magnify the object.

You

You are to determine what three objects you would have appear under the three perspectives; and supposing, for example, that they are represented by the numeral figures 1, 2, and 3, you will find that these three figures will admit of six combinations or different dispositions, as

1, 2, 3. 1, 3, 2. 2, 1, 3. 2, 3, 1. 3, 1, 2. 3, 2, 1*.
Then place the numbers, or the objects they represent, in such order that the first number, 1, of the first combination, 1, 2, 3, may be in the first division A, of the circle, (see Fig. 7.) the second number, 2, in the eighth, and the third number, 3, in the fifteenth division: that the first number, 1, of the second combination, may be placed in the second division B; the second number, 3, in the ninth division; and the third number, 2, in the sixteenth division, &c. Having thus filled up eighteen of the divisions with the six combinations of numbers, the other three are to be left blank.

* See vol. I. page 9. aphorism 16.

The circle being thus prepared, is to be placed on its pivot, and to one of the seven sides of the box (Fig. 4.) is to be adjusted a lever or stop, that being let down on the circle, at pleasure, may prevent it from turning.

When the three perspectives are placed on the box, and turned toward the column erected on its center, if the smallest tube be thrust in, it raises the mirror that is contained in each of them, and, by the hole **B** the column is seen. If on the contrary the small tube be drawn a little way out, the mirror becomes inclined, and you then see one of the three objects that are placed in the box, under each opening in the stands of the perspective, and these objects will necessarily appear in the order of one of the six combinations of which they are alone susceptible.

By placing the box on the table, in which a magnetic bar, six inches long,

long*, must be concealed, and whose direction you know, you may easily make the three objects above mentioned appear opposite the three holes O, P, Q, with all their changes; for nothing more is necessary than to place the box according to a mark that is on the table, opposite to which you are to place one of its seven sides; and by letting down the private check you keep the circle fixed.

The amusements that are to be made with these perspectives may be varied according to the number of different objects that can be placed on the moveable circle. We shall content ourselves here with giving an example in numbers, which may be applied to any other subject, the difference of objects making not the least difference in the manner of performing this Recreation; which, when well executed,

* This bar should be strongly impregnated, that it may readily turn the pasteboard circle.

never fails to excite the highest admiration.

First then, you are so to place the moveable circle, that the three divisions on which there is nothing wrote may appear under the three holes O, P, Q*, and the small tube of the perspectives is to be so disposed that the mirrors on the inside may incline to forty-five degrees †, and reflect the objects placed under those holes. The perspectives being thus disposed, they are placed on the table, and liberty is given those that desire it, to look into them, as they can then see no object. You are then to present to three different persons, three such objects as you shall think proper ‡;

* This must be done privately, by means of the check, before the machine is brought to the table.

† That is, be half way between a line drawn perpendicular to the ground, and its surface.

‡ These objects may be either numbers, flowers, cards, mottos, &c. it is only necessary that the circle be properly painted. You may also have different circles to vary the Recreation yet farther, by privately changing them.

we

we will suppose here the three numbers 1, 2, 3. When each of the three persons has made choice of one of these numbers, you roll the three cards on which they are wrote, altogether, and put them into the column, opposite to which the three perspectives are placed ; and give each person liberty to choose in which glass he will see his object*.

When the three parties have chose their perspectives, the box is to be placed on the table, where the bar is concealed, taking due care to set it in such direction that the openings O, P, Q, may correspond to those parts of the circle on which the objects are wrote. A short time must be given the circle to settle, and then the

* It is immaterial which glass the first person chooses, before the box is placed on the table, but if the second should not name that under which his object is placed, the box must be moved ; however it is an equal chance but he does, and in that case they may all three see their objects at the same time.

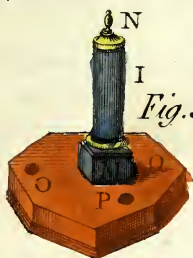
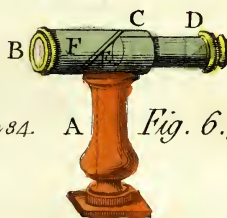
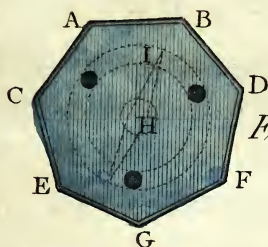
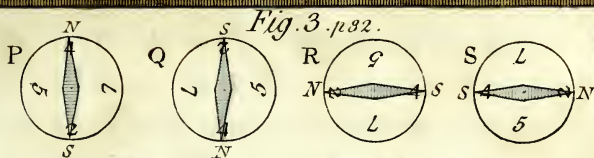
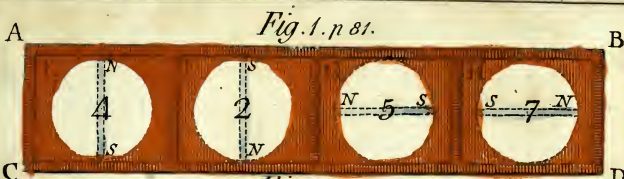
check

check must be privately let down. The three persons then looking through the perspective they have each of them chose, their objects will naturally appear to them in that part of the column where their cards were placed*.

Note, It requires some memory to perform this recreation with facility, as you must keep in mind the fix changes of order, which the liberty you give the spectators to see through which of the glasses they please, requires. You may, however, to avoid charging your memory, trace on the box certain signs, which at the same time that they appear to be ornaments, may show you in what direction the box is to be placed.

* You may then propose to each of them to make him see his object through another perspective, which you do by removing the check, and putting the box in a different direction.

R E C R E-





RECREATION XXI.

The penetrating perspective.

WITHIN the case ABCD, (Plate X. Fig. 1.) place four mirrors, O, P, Q, R, so disposed that they may each of them make an angle of forty-five degrees, that is, that they may be half way inclined from the perpendicular, as in the figure. In each of the two extremities AB, make a circular overture, in one of which fix the tube GL, in the other the tube MF, and observe that in each of these is to be inserted another tube, as H and I*.

Furnish the first of these tubes with an object glass at G, and a concave eye-glass at F. You are to observe that, in regulating the focus of these glasses with regard to the length of the tube, you are to sup-

* These four tubes must terminate in the substance of the case, and not enter the inside, that they may not hinder the effect of the mirrors.

pose.

pose it equal to the line G, or visual pointed ray, which entering at the overture G, is reflected by the four mirrors, and goes out at the other overture F, where the ocular glass is placed. Put any glass you will into the two ends of the moveable tubes H and I ; and lastly place the machine on a stand E, moveable at the point S, that it may be elevated or depressed at pleasure.

When the eye is placed at F, and you look through the tube, the rays of light that proceed from the object T, passing through the glass G, are successively reflected by the mirrors O, P, R, and Q, to the eye at F, and there paint the object T, in its proper situation, and these rays appear to proceed directly from that object.

The two moveable tubes H and I, at the extremities of each of which a glass is placed, serve only the more to disguise the
illusion

illusion, for they have no communication with the interior part of the machine. This instrument being moveable on the stand E, may be directed to any object; and if furnished with proper glasses will answer the purpose of a common perspective.

The two moveable tubes H and I being brought together, the machine is directed toward any object, and desiring a person to look in at the end F, you ask him if he see distinctly that object. You then separate the two moveable tubes, and leaving a space between them sufficient to place your hand, or any other solid body, you tell him that the machine has the power of making objects visible thro' the most opaque body; and as a proof you desire him then to look at the same object, when to his great surprize, he will see it as distinct as when there was no solid body placed between the tubes.

Note,

Note, This recreation is the more extraordinary, as it is very difficult to conceive how the effect is produced. The two arms of the case appearing to be made to support the perspective glass; and to whatever object it is directed, the effect is still the same.

R E C R E A T I O N XXII.

The magician's mirrors.

IN the wainscot of a room make two overtures, of a foot high, and ten inches wide, and about a foot distant from each other. Let them be at the common height of a man's head; and in each of them place a transparent glass, surrounded with a frame, like a common mirror.

Behind this partition place two mirrors, one on the outward side of each overture, inclined to the wainscot in an angle of forty-five degrees*; let them be both eighteen inches square: let all the space be-

* See page 90.

tween,

tween them be enclosed by boards or paste-board, painted black, and well closed, that no light may enter; let there be also two curtains to cover them, which may be drawn aside at pleasure.

When a person looks into one of these supposed mirrors, instead of seeing his own face he will perceive the object that is in the front of the other; so that if two persons present themselves at the same time before these mirrors, instead of each one seeing himself, they will reciprocally see each other.

Note, There should be a sconce with a candle placed on each side of the two glasses in the wainscot, to enlighten the faces of the persons who look in them, otherwise this experiment will have no remarkable effect.

This Recreation may be considerably improved by placing the two glasses in the

VOL. II. H wainscot,

wainfcot, in adjoining rooms, and a number of perfons being previously placed in one room, when a ftranger enters the other, you may tell him his face is dirty, and defire him to look in the glafs, which he will naturally do; and on feeing a ftrange face he will draw back: but returning to it, and feeing another, another, and another, like the phantom kings in Macbeth, what his furprife will be is more eafy to conceive than exprefs. After this, a real mirror may be privately let down on the back of the glafs, and if he can be prevailed to look in it once more, he will then, to his farther aftonifhment, fee his own face; and may be told, perhaps perfuaded that all he thought he faw before was mere imagination.

How many tricks lefs artful than this, have paffed in former times for forcery; and pafs at this time, in fome countries, for apparitions:

Note, When a man looks in a mirror that is placed perpendicular to another, his
face

face will appear entirely deformed. If the mirror be a little inclined, so as to make an angle of eighty degrees (that is one ninth part from the perpendicular) he will then see all the parts of his face except the nose and forehead. If it be inclined to sixty degrees (that is, one third part) he will appear with three noses and six eyes: in short, the apparent deformity will vary at each degree of inclination; and when the glass comes to forty-five degrees, (that is, half way down) the face will vanish. If instead of placing the two mirrors in this situation, they are so disposed that their junction may be vertical, their different inclinations will produce other effects; as the situation of the object relative to these mirrors is quite different. The effects of these mirrors, though remarkable enough, occasions but little surprize, as there is no method of concealing the cause by which they are produced.

R E C R E A T I O N XXIII.

Polemoscopes.

BY the term polemoscope is meant any instrument, whether catoptric or dioptric, by which you may see what passes in another place, without being seen from thence. The machines contain one or more plane mirrors, which convey by reflection the image of the object to the eye of the spectator. There are small instruments of this kind, made in the form of an opera-glass, by which, while you seem to look straight forward, you see what passes on one side, and by that means gratify your curiosity without the appearance of incivility.

To the constructing of this sort of polemoscope nothing more is necessary than to fix in a common opera-glass a small mirror inclined to an angle of forty-five degrees, and adjust a proper object-glass. This glass at the same time may answer
its

its common use, by adding an object-glass, and so contriving the small tube that it may remove the mirror at pleasure, as in the 21st Recreation.

The tube of a polemoscope may be placed against a wall, the inclined mirror being a little above it, and turned outwards, by which means you will discover what passes on the other side, without being seen yourself. An instrument of this sort would be of use in sieges, where there is danger without the wall from the fire of the enemy; and on other occasions. This instrument may be also so constructed, that the tube may turn round, and the mirror be elevated or depressed, that you may see successively and at pleasure, all the objects that you would perceive if you were at the top of the wall against which the instrument is placed.

R E C R E A T I O N XXIV.

The enchanted mirrors.

MAKE a box of wood, of a cubical figure, A C B D, (Plate X. Fig. 2.) of about fifteen inches every way. Let it be fixed on the pedestal P, at the usual height of a man's head. In each side of this box let there be an opening of an oval form, of ten inches high, and seven wide.

In this box place two mirrors A, D, with their backs against each other; let them cross the box in a diagonal line, and in a vertical position. Decorate the openings in the sides of this box with four oval frames and transparent glasses, and cover each of them with a curtain, so contrived that they may all draw up together.

Place four persons in front of the four sides, and at equal distances from the box, and then draw up the curtains that
they

they may see themselves in the mirrors; when each of them, instead of his own figure, will see that of the person who is next him, and who, at the same time, will seem to him to be placed on the opposite side. Their confusion will be the greater, as it will be very difficult for them to discover the mirrors concealed in the box. The reason of this phenomenon is evident, for though the rays of light may be turned aside by a mirror, yet, as we have before said, they always appear to proceed in right lines.

RECREATION XXV.

The animated optic balls.

(By a single reflection.)

THIS piece of catoptrics, as well as that which follows of double reflection, being of the class that produces the most pleasing illusion, we shall here give a full detail of the manner in which it is to be executed.

Provide a wooden box ABCD, of about two feet high, and fifteen inches wide (Plate IX. Fig. 1.) and toward the top let there be made an opening E, of eight or nine inches high, and seven or eight inches wide, and in this opening fix a transparent glass*. Let the box be two feet deep (see the profile ABCD, Fig. 2.) and adjust to it a partition ST, of the same width, and that is fifteen inches deep from S to T; observe, that this partition will separate the box into two divisions, the upper of which must be one or two inches less than the under.

In the upper division, and toward the extremity S of the partition ST, and cross it, place a small decoration KS, of the figure of the outward scene of a theatre, in which let there be an opening of ten inches wide, and eight inches high.

* If the dimensions of the box be larger, the exhibition will be more perfect; and on the contrary, if it be smaller, it will be less perfect.

Behind

Behind this scene place the mirror KF, (Fig. 2.) in an angle of forty-five degrees, as in the common optical machines, and observe that it be of the same width with the box, and large enough to cover the overture of the front scene, when the eye is placed at the transparent glass E.

Decorate the interior space K S B T, with such different paintings as you shall judge will contribute most to the pleasure of the exhibition. Cover the top of the box, from K to B, with a frame in which is a glass lined with gauze, that the light may enter the part K S B T. This first construction being made in the proportions and with the precautions here laid down, you are next to place the inclined plane, hereafter described, which must be of a size to enter this edifice by a back door made at G H.

Construction of the inclined plane.

This plane should incline to the base of the structure in an angle of about thirty degrees,

degrees*, that is, it should be raised about one third of the space toward the perpendicular, and must be supported on its sides by two triangular props, placed at I M L.

On that part of this plane with faces the mirror K F, draw some pleasing subject, as for example, a garden ornamented with bowers; or a piece of architecture, &c. in such manner that it may appear regular when seen at E, by reflection from the inclined mirror †.

In this plane form a groove made of two thin slips of copper, very little elevated above the surface; let this groove be so disposed that the ball in going from the

* If the ball that is to run down this plane make many turnings, the plane should then have a greater inclination.

† This drawing need not differ much from the common method; for as the plane I M is but little inclined, it will be only necessary to draw the objects a little higher: their width may remain the same.

top

top may make various windings, over such parts of the drawings as you shall think fit, and at last descending near the middle of its inferior side CD, (Fig. 3.) and running along the channel OP, (Fig. 2.) it may fall into a part made to receive it in the wheel hereafter described.

Provide yourself with several ivory balls of something more than half an inch diameter, which are to run freely in the groove above described.

On the inside of this box, towards R, place two small tin candlesticks, in which put two wax candles to enlighten the inclined plane*; there must be a door by which you may take them out at pleasure: fix over them a cover of tin, to which there must be a funnel to carry the smoke out of the edifice.

* To these candlesticks may be joined reflectors, so disposed as to throw all the light on the inclined plane.

Con-

Construction of the wheel for remounting the balls incessantly.

In the centre of the toothed wheel A, (Pl. IX. Fig. 5.) place a barrel with a spring, and let it be also in the centre of the brass rod FG. The pinion of the wheel B is to take the teeth of the first wheel A; and its teeth are to turn the fly C, whose wings must be moveable, that by being more or less inclined, they may accelerate or retard the motion of the machine.

To the wheel A let there be fixed two brass rods*, and at the extremity of each there must be a box D, (see the profile Fig. 6.) whose overture MN is closed by a valve H, that moves freely on the point I: the axis of this valve must come out beyond the surface of the box, that the check L may be there placed, which

* The axis of this wheel should project, that it may be wound up by a key, in the same manner as a clock.

should

should move freely, and at the same time with the valve. These boxes must be large enough to contain, each of them, one of the balls, that are, as we have said, to roll on the inclined plane, and that it may enter at the side M of the valve, which must then close. The sides of these boxes must incline, as in Fig. 5.

Observe also, that this wheel must be of a proper size to place at the back of this machine, near that part where the inclined plane is placed, (see Fig. 4.) that it may not only receive in its revolving boxes the balls, that after having rolled on the plane, pass out by the groove OP, (Fig. 2.) but may also raise them again to the height C, (Fig. 4.) where there should be a small channel to receive and conduct them to the top of the inclined plane. Remark, also, that toward the part M there must be a little iron catch, that may successively stop the cheeks L, (Fig. 6.) which are fixed to the axis of the valves, that it
 may

may give time to the ball to pass into the box at the part M, and discharge the check L: in like manner when the box comes to the height of the groove that is to conduct the ball to the inclined plane, there must be another catch to open the valve and discharge the ball.

The wheel being thus placed, at the back of the machine, and the spring wound up, the balls will incessantly descend and remount till the spring in the box at the axis of the wheel is quite unbent*.

When a ball is put into the groove at the top and runs down the inclined plane, he that looks into the glass placed in front of the box, will imagine that it ascends by various turnings, and goes out at the top of the edifice. The appearance will become the more pleasing as the different

* There should be a case over this wheel, with a door to open, that the contrivance may be quite free from detection.

windings of the ball are properly adapted to the subject painted on the inclined plane. This piece when executed with care, produces a very remarkable illusion, and is one of the most pleasing Recreations of catoptrics.

RECREATION XXVI.

The same exhibition by a double reflection.

THIS differs from the foregoing by having a mirror inclined in an angle of forty-five degrees, (see Plate IX. Fig. 2.) in the room of the inclined plane, and by having the plane on which the balls roll placed near the part of the box T D.

There may be placed, moreover, toward S T, and in a position almost horizontal, little columns, arbours, or other objects, made of brass wire, at equal distances*,

* This wire should have a small inclination, which may be two tenths of an inch for every foot ; and the distance between the wires should be something less than the diameter of the balls.

and

and joined together at the bottom by semi-circles, which must be so contrived as not to obstruct the course of the ball.

If there be sufficient room, you may place, under the former, another range of wires, that have a similar disposition, so that the ball, after having run over the first, may descend to the other, which will have a remarkable effect; as the balls will seem to rencounter and pass over each other. There must then be two conductors, so that one ball may enter at one side, and the other at the opposite side. There should also be a third conductor, which, after the ball has passed over the first piece, may carry it to the top of the inclined plane, placed opposite the second mirror, that it may then pass through all its windings.

Note. These exhibitions may be varied at pleasure, as that depends entirely on the taste and invention of those that construct

Fig. 2. p. 104.



Fig. 1. p. 104.

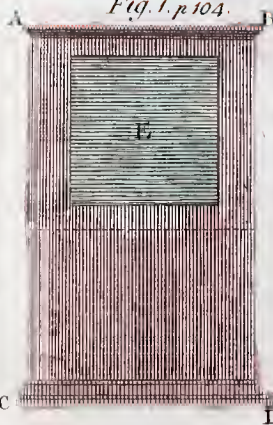


Fig. 4. p. 109

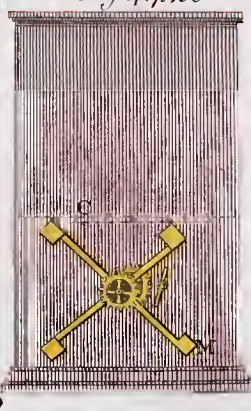


Fig. 3. p. 107. B

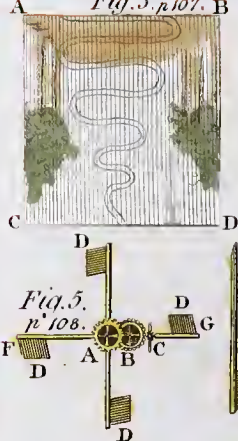


Fig. 5. p. 108.

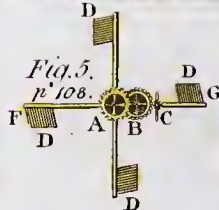
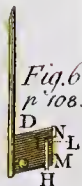


Fig. 6. p. 108.



struct them. You should observe to give but a very small inclination to the grooves in which the balls run. These balls may be of ivory painted, as those of brass make too much noise in the box, and are subject to break the inclined mirror, when by chance they jump out of the groove and fall on it.

The grooves should be concealed as much as possible by paintings or ornaments. They should be either of brass, tin or thin pasteboard. In a word, too much care cannot be taken in conducting exhibitions of this nature.

RECREATION XXVII.

To describe on a plane surface an irregular figure, which shall appear regular when placed opposite a multiplying glass, and seen by reflection through an aperture made in the center of the drawing.

WE shall not here lay down the geometric manner of drawing this figure, for it would not only be very complicated, and extremely difficult to execute, but when done could not succeed, on account of the impossibility of procuring glasses of this sort, whose planes are equally inclined and perfectly regular.

C O N S T R U C T I O N.

Procure of an able artist a mirror of metal (Plate X. Fig. 3.) whose base is a hexagon of about two inches and a half in diameter, and about half an inch thick at its center. Let the faces of this mirror be very truly cut, their angles very sharp,
and

and their surfaces highly polished. Cement this mirror to a stand of about half an inch thick, and let it be firmly joined by means of a screw, at the point A, (Fig. 4.) which should be eight or nine inches high; and let the stand be solidly fixed on the top of the box BC*.

At the end C of this box (Fig. 4.) place an upright frame with a groove, which is to remain there, and in which are to be placed the designs, of about fifteen inches square, containing the different distorted figures that are to appear regular, when seen in the glass, which, as appears by the figure, will then be opposite to it.

In the center of the drawing make a hole of about three tenths of an inch in diameter, through which the mirror may be entirely seen, and which should be placed

* This box may have a drawer, to contain the different paintings that are to be seen by the mirror: it may be eight or nine inches wide, and fifteen inches deep.

exactly opposite that hole, with its base parallel to the drawing or picture.

Draw on a paper or pasteboard the geometric plan of the multiplying glafs, (see Fig. 6.) and on that draw the design you would have seen in the mirror. These preparations being made with great attention, that is, the mirror being properly fixed, and the drawing rightly adjusted, look at the mirror through the hole H, made in the drawing, and holding the ruler A B*, by its handle D, (see Fig. 5.) in your left hand, move it in different directions over the drawing till its side C appear to the eye (remaining constantly at H) to be exactly even with one of the sides of the glafs ; there keep it fixed ; and taking the eye from the hole, draw with a black lead pencil, that you have ready in the other hand, a line by the

* This ruler should be about three or four inches long, very thin and black. It may be made of part of the spring of a clock.

ruler

ruler. Do the same by the other sides of that face of the glass, and then the space contained between those two lines will be that on which you are to transpose that part of the design which is drawn on the corresponding face in Fig. 3.

Do the same by all the other faces of the glass, and you will then have twelve faces that will correspond to those of the mirror, and which altogether must consequently contain the entire subject that is traced on Fig. 6.

These spaces not differing much from those of the mirror, it will be easy to trace the object that has been designed ; it will be only necessary to number them, to prevent any mistake ; and to place the paper or pasteboard before the mirror, after you have lightly traced the design ; and inspect it by the hole H, that you may discover and rectify any errors that may have been made. These spaces may also be subdivided

I 3

vided, as well on the design as the distorted figure, in the manner expressed in Fig. 7, 8; and by that means the transposition will be made with still greater facility.

Lastly, you should fill up the vacant parts on the pasteboard with figures that have no analogy with those in the original design, and by that means render it still more surprising.

This experiment will produce a most agreeable illusion to those who are ignorant of the manner in which it is performed; for, when looking at the point H, they cannot discover the least resemblance between what they see in the mirror, and the general design on the pasteboard.

Observe, this drawing may also be traced correctly enough by means of a lamp, placed at the point of view H, taking care to enclose it in a tin case, and
to

Fig. 1. p. 93.

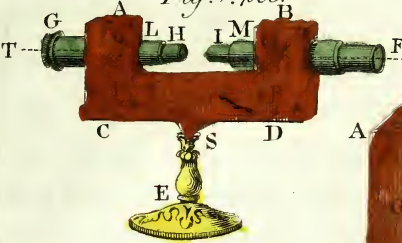


Fig. 2. p. 102.

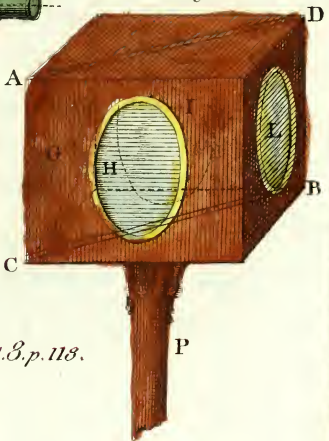


Fig. 7. p. 113.



Fig. 3. p. 113.



Fig. 6. p. 116.

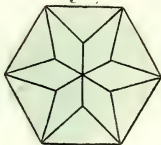


Fig. 4. p. 115.

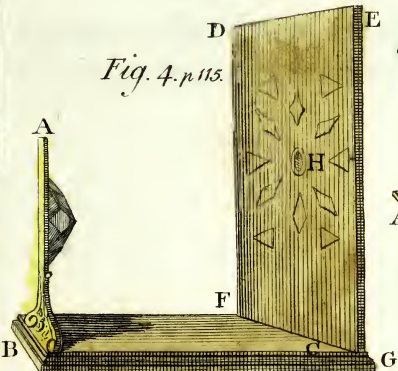
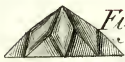


Fig. 5. p. 116.



Fig. 3. p. 114





to adjust to it a tube of about an inch in diameter, and three or four inches long, that can be protracted or shortened at pleasure. When you use this method, a hole must be made in the paper, large enough to admit the end of the tube ; so that the light falling on the several faces of the glass, they may be reflected on the paper, and show where each of them is to be traced. By this method the time spent in finding them by the ruler is saved ; and if the light be steady, the drawing will answer very well. You may also draw on the mirror, with foot, tempered with fine white lead, all the strokes of the design, and by that means still shorten the execution of the drawing.

R E C R E A T I O N XXVIII.

To describe on a plane surface a deformed figure, which shall appear regular when viewed by reflection in a cylindrical mirror.

THE geometric method of describing this irregular figure, being, as in the last Recreation, not only extremely difficult, on account of its different curves, but also liable to error from the want of regularity in making the mirrors; we shall here shew another method of describing it, far less learned indeed, but much more concise, and easily practicable by those who have not a profound knowledge of geometry, but are yet desirous of drawing these sorts of anamorphoses

Let ABCD be the cylindrical mirror, (Plate XI. Fig. 1.) in which you would see,
from

from the point of view E, the deformed object painted on the board FG, in a regular form.

On a paper, or pasteboard, draw the circle A (Fig. 2.) equal to the base BD of the cylindric mirror; and taking the point B for the distance of the point of view from the mirror, draw the line AB, which must pass through A, the center of the circle. Then draw the two lines BC and BD.

Divide the line CD into six equal parts, and draw from the point of view B, the lines Bi, which by cutting one of the sides of the circle, will determine the points on which you are to erect the parallel perpendiculars, which may be done by a ruler; making use of an opaque colour that will effectually obscure those parts of the cylinder where they are drawn*.

* You may use foot and white lead ground together with gum, after having traced the lines with a crayon.

These

These first divisions being regularly made, divide about two thirds of the height of the side CD, of the cylinder, into ten or twelve parts, respectively equal to those of the diameter of the circle (Fig. 2.) and from the point of view E, draw the lines El, which passing through all the points of division, must be continued to the other side of the cylinder. On the two opposite sides of the cylinder mark the different heights of the several divisions, and through those points draw the oval figures il, making use of the same colour as before.

Take a paper ABCD (Fig. 3.) whose two sides AB and CD must be divided into six equal parts, and those of AC and BD into ten or twelve equal parts, on which you are to draw the figure as you would have it appear to the eye when viewed in the cylindric mirror. At the point of view E, place a lamp so disposed that its light may fall on the cylindric mirror only.

When

When you have fixed the cylinder on the pasteboard F G (Fig. 1.) and the lamp is placed at E, so that its light cannot fall on the pasteboard, but by reflection, all the strokes on the cylinder will then appear on the board, and may be easily traced with a pencil. By this means the board will be divided into as many irregular spaces, as there are regular divisions in the parallelogram (Fig. 8.) If, therefore, you transfer to each of those spaces the strokes of the design that is on the parallelogram, it will appear quite deformed on the pasteboard, and quite regular when seen from the point of view E, especially if due attention be had to drawing the outlines of the figure.

Note, The point of view should be four or five inches above the upper part of the mirror, that you may not be obliged to make use of a very large pasteboard: it should not, however, be much higher, as then the figure on the board would not be sufficiently deformed.

By

By this method you may also draw irregular figures to be seen in a prism, or any other sort of mirror, provided they can be traced and illuminated*.

Observe, if you are desirous of painting these sorts of anamorphoses to advantage, you must not overcharge those parts with colour that are most distended, for when they become contracted in the mirror the colours appear unnatural. In a word, great attention is necessary in drawing and painting these subjects, as on that the success principally depends.

* The geometric method of drawing deformed objects to be seen in a prism, will be found at large in the treatise of Abbé Nollet.

R E C R E -

RECREATION XXIX.

Optical appearances.

OF all our senses the sight is certainly subject to the greatest illusion. The various writers on optics have described a great number of instances in which it deceives us, and have constantly endeavoured to investigate the causes, to explain their effects, and to reconcile appearance with reality. We every day discover new phenomena, and doubtless many more are reserved for posterity. It frequently happens, moreover, that a discovery which at first seemed of little consequence, has led to matters of the highest importance.

Take a glass bottle A, (Pl. XI. Fig. 4.) and fill it with water to the point B; leave the upper part BC, empty, and cork it in the common manner. Place this bottle opposite a concave mirror, and beyond its focus, that it may appear reversed, and before

fore the mirror (see aphorism 4. page 65.) Place yourself still farther distant than the bottle, and it will appear to you in the situation *a, b, c*, (Fig. 5.)

Now it is remarkable in this apparent bottle, that the water, which, according to all the laws of catoptrics, and all the experiments made on other objects, should appear at *ab*, appears on the contrary at *bc*, and consequently the part *ab* appears empty.

If the bottle be inverted and placed before the mirror (as in Fig. 6.) its image will appear in its natural, erect position; and the water, which is in reality at *BC*, will appear at *ab*.

If while the bottle is inverted it be uncorked, and the water run gently out, it will appear that while the part *BC* is emptying, that of *ab* in the image is filling; and what is likewise very remarkable,

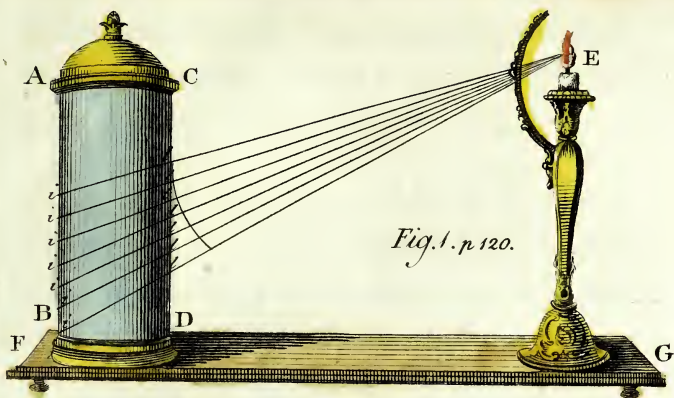


Fig. 1. p. 120.

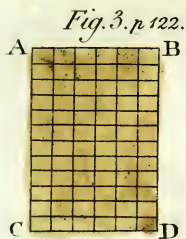


Fig. 3. p. 122.

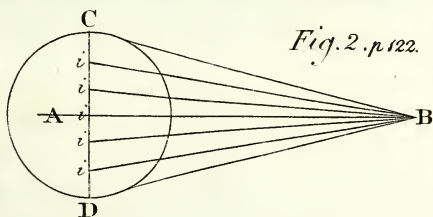


Fig. 2. p. 122.

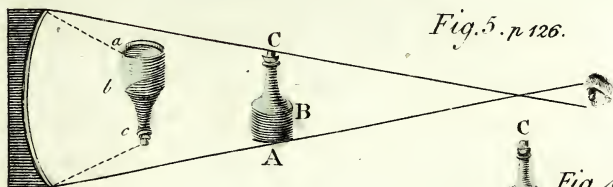


Fig. 5. p. 126.



Fig. 4. p. 125.

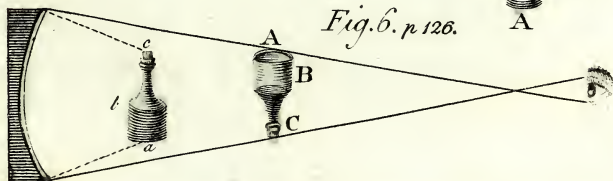


Fig. 6. p. 126.



able, as soon as the bottle is empty the illusion ceases, the image also appearing entirely empty. If the bottle likewise be quite full there is no illusion.

If while the bottle is held inverted, and partly empty, some drops of water fall from the bottom *A* towards *BC*, it seems in the image as if there were formed at the bottom of the part *ab*, bubbles of air that rose from *a* to *b*; which is the part that seems full of water. All these phenomena constantly appear.

The remarkable circumstances in this experiment, are, first, not only to see an object where it is not, but also where its image is not; and secondly, that of two objects which are really in the same place, as the surface of the bottle and the water it contains, the one is seen at one place, and the other at another; and to see the bottle in the place of its image, and the water where neither it, nor its image, are.

Note,

Note, It has been conjectured, with some appearance of reason, that this illusion arises partly from our not being accustomed to see water suspended in a bottle with the neck downward, and partly from the resemblance there is between the colour of the air and that of water, which induces us to imagine that we see them where they usually are; and this is rendered more probable by putting any coloured liquor into the bottle, for that will appear in its proper place (M. Guyot.)

R E C R E A T I O N X X X .

The perspective mirror.

PROVIDE a box ABCD (Pl. XII. Fig. 1.) of about two feet long, fifteen inches wide, and twelve inches high. At the end AC place a concave mirror, the focus of whose parallel rays is at eighteen inches from the reflecting surface. At IL place a pasteboard blacked, in which
a hole

a hole is cut sufficiently large to see on the mirror H, the object placed at BEFD.

Cover the top of the box, from A to I, close, that the mirror H, may be entirely darkened. The other part I B, must be covered with a glass, under which is placed a gauze.

Make an aperture at G, near the top of the side EB; beneath which, on the inside, place, in succession, paintings of different subjects, as vistas, landscapes, &c. so that they may be in front of the mirror H. Let the box be so placed that the object may be strongly illumined by the sun, or by wax lights placed under the enclosed part of the box AI.

By this simple construction the objects placed at GD will be thrown into their natural perspective, and if the subjects be properly chose, the appearance will be altogether as pleasing as in optical machines of a much more complicated form.

Note, A glass mirror should be always here used, as those of metal do not represent the objects with equal vivacity, and are beside subject to tarnish. It is also necessary that the box be sufficiently large, that you may not be obliged to use a mirror whose focus is too short; for in that case, the right lines near the border of the picture will appear bent in the mirror, which will have a disagreeable effect, and cannot be avoided.

R E C R E A T I O N XXXI.

To set fire to a combustible body, by the reflection of two concave mirrors.

THE rays of a luminous body placed in the focus of a concave mirror being reflected in parallel lines, if a second mirror be placed diametrically opposite the first, it will, by collecting those rays in its focus, set fire to a combustible body.

Place two concave mirrors, A and B (Pl. XII. Fig. 2.) at about twelve or fifteen feet

feet distance from each other, and let the axis of each of them be in the same line. In the focus C, of one of them, place a live coal, and in the focus D of the other, some gunpowder. With a pair of double bellows, which make a continual blast, keep constantly blowing the coal, and notwithstanding the distance between them the powder will presently take fire.

It is not necessary that these mirrors be of metal or glass, those made of wood or pasteboard, gilded, will produce the explosion, which has sometimes taken effect at the distance of fifty feet, when mirrors of eighteen inches or two feet diameter have been used.

This experiment succeeds with more difficulty at great distances ; which may proceed from the moisture in a large quantity of air. It would doubtless take effect more readily, if a tin tube, of an equal diameter with the mirrors, were to placed between them.

R E C R E A T I O N XXXII.

The real apparation.

BEHIND the partition AB (Pl. XII. Fig. 3.) place, in a position something oblique, the concave mirror EF, which must be at least ten inches in diameter, and its distance from the partition equal to three-fourths of the distance of its center.

In the partition make an opening of seven or eight inches, either square or circular: it must face the mirror; and be of the same height with it. Behind this partition place a strong light, so disposed that it may not be seen at the opening, and may illumine an object placed at C, without throwing any light on the mirror.

Beneath the aperture in the partition place the object C; that you intend shall appear on the outside of the partition, in an inverted position; and which we will suppose

suppose to be a flower. Before the partition, and beneath the aperture, place a little flower-pot D, the top of which should be even with the bottom of the aperture, that the eye, placed at G, may see the flower in the same position as if its stalk came out of the pot.

Take care to paint the space between the back part of the partition and the mirror black, to prevent any reflections of light from being thrown on the mirror; in a word, so dispose the whole that it may be as little enlightened as possible.

When a person is placed at the point G, he will perceive the flower that is behind the partition, at the top of the pot at D, but on putting out his hand to pluck it, he will find that he attempts to grasp a shadow.

Observation.

The phenomena that may be produced by means of concave mirrors are highly

curious and astonishing. By their aid spectres of various kinds may be exhibited. Suppose, for example, you were to tell any one, that at such an hour, and in such a place, he should see the apparition of an absent or deceased friend (of whose portrait you are in possession.) In order to produce this phantom, instead of the hole in the partition A B, in the last figure, there must be a door, which opens into an apartment to which there is a considerable descent. Under that door you are to place the portrait, which must be inverted and strongly illuminated, that it may be lively reflected by the mirror, which must be large and well polished. Then having introduced the incredulous spectator at another door, and placed him in the proper point of view, you suddenly throw open the door at A B, when to his great astonishment, he will immediately see the apparition of his friend.

It will be objected, perhaps, that this is not a perfect apparition, because it is only
vifible

Fig. 1. p 128.

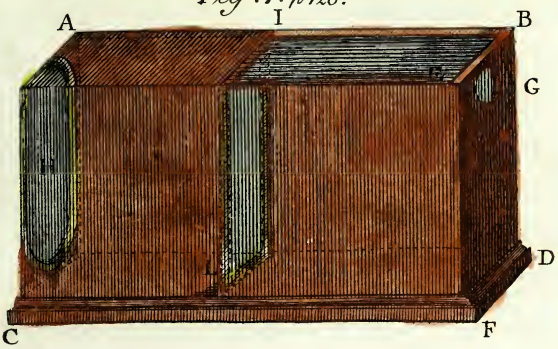


Fig. 2. p 130.

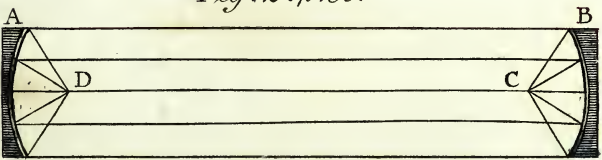
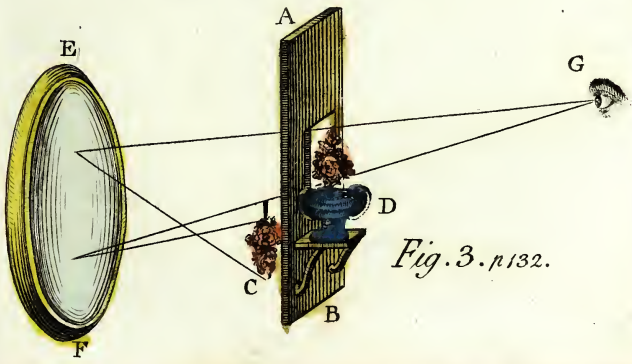


Fig. 3. p 132.





visible at one point of view, and by one person. But it should be remembered, that it was an established maxim in the last centuries, that a spectre might be visible to one person and not to others. So Shakespeare makes both Hamlet and Macbeth see apparitions that were not visible to others, present at the same time. It is not unlikely, moreover, that this maxim took its rise from certain apparitions of this kind that were raised by the monks, to serve some purposes they called religious; as they alone were in possession of what little learning there then was in the world.

Nothing here said is intended to invalidate the belief that separate spirits may hold converse with men. He must be either very weak or very wicked, who can wish to disbelieve an opinion that is so highly honourable and advantageous to humanity.

There is one phenomenon we must not here omit; for tho' it be common enough

it is also pleasing, and easy to be performed. If you place yourself before a concave mirror and at a proper distance, your figure will appear inverted, and if you stretch out your hand toward the mirror, you will perceive another hand that seems to meet and join it, though imperceptible to the touch. If instead of your hand you make use of a drawn sword, and present it in such manner that its point may be directed toward the focus of the parallel rays of the mirror, another sword will appear, and seem to encounter that in your hand. You are to observe, that to make this experiment succeed well, you must have a mirror of at least a foot in diameter, that you may see yourself in part. If you have a mirror large enough to see your whole person, the illusion will be much more striking. This phenomenon, with which so much parade has been made by some modern experimental philosophers, was described by Baptista Porta more than 200 years since.

C H R O-

CHROMATICS.

CHROMATICS is that part of optics which explains the several properties of the colours of light, and of natural bodies.

DEFINITIONS.

1. Those rays of light that are all equally refrangible, are called simple or homogeneous rays.

2. Those rays that have different degrees of refrangibility, are called compound, or heterogeneous*.

3. The colours of homogeneous light are called primary or simple colours: and

4. Those of heterogeneous light, secondary or compound colours.

5. A spectrum is a coloured image of the sun, produced by the refraction of a ray of light let into a dark chamber.

* The terms homogeneous and heterogeneous are derived from the Greek words *omos*, *the same*; *eteros*, *another*; and *genos*, *kind* or *species*.

6. A prism is a glass body, whose two ends are similar and parallel triangles, and its three sides regular planes.

A P H O R I S M S.

1. All the colours in nature proceed from the rays of light.

2. There are seven primary colours, which are red, orange, yellow, green, blue, indigo, and violet.

3. Every ray of light may be separated into the seven primary colours.

4. The rays of light in passing through the same medium have different degrees of refrangibility.

5. The difference in the colours of light arises from its different refrangibility, that which is the least refrangible producing red, and that which is the most refrangible, violet*.

* It is conjectured that the different refrangibility in the rays of light proceeds from their different magnitude: those of red light, being the largest, make

6. By compounding any two of the primary colours, as red and yellow, or yellow and blue, the intermediate colour, as orange or green, may be produced.

7. The colours of bodies arise from the dispositions to reflect one sort of rays, and to absorb the other. Those that reflect the least refrangible rays appearing red; and those that reflect the most refrangible, violet*.

make the strongest impression on the retina; and those of violet, being the smallest, make the weakest impression.

* It appears highly probable, from observations made by Sir Isaac Newton, that the disposition of bodies to reflect the different rays of light, arises from the different size of their particles. Thus, the azure colour of the sky, and the most luminous white, as that of metals, he supposes to be produced by particles of the first order; but if the white be less intense, as that of linen, paper, and such like substances, he conjectures that it arises from a mixture of particles of all orders. The green of vegetables he supposes to proceed from the third order, and the particles that cause blackness, to be smaller than those that produce any of the colours.

8. Such

8. Such bodies as reflect two or more sorts of rays, appear of various colours.

9. The whiteness of bodies arises from their disposition to reflect all the rays of light promiscuously.

10. The blackness of bodies proceeds from their incapacity to reflect any of the rays of light*.

RECREATION XXXIII.

Out of a single colourless ray of light to produce seven other rays, which shall paint, on a white body, the seven primary colours of nature.

PROCURE of an optician a large glass prism DEF, (Plate XIII. Fig. 1.) well polished, two of whose sides must contain an angle of about sixty-four degrees. Make a room quite dark, and in the window shutter AB, cut a round hole, about

* From hence it arises that black bodies, when exposed to the sun, become sooner heated than all others.

one-

one-third of an inch in diameter at C, through which a ray of light LI passing, falls on the prism DEF, by that it is refracted out of the direction IT, in which it would have proceeded, into another GH, and falling on the paper MNSX, will there form an oblong spectrum PQ, whose ends will be semicircular, and its sides strait; and if the distance of the prism from the paper be about eighteen feet, it will be ten inches long, and two inches wide.

Now this spectrum will exhibit all the primary colours; for the rays between P and V, which are the most refracted, will paint a deep violet; those between V and I, indigo; those between I and B, blue; those between B and G, green; those between G and Y, yellow; those between Y and O, orange; and those between O and R, being the least refracted, an intense red*. The colours between these

* For this reason it is that the rays which are near the edges of a lens have different degrees of refraction,

spaces will not be every where equally intense, but will incline to the neighbouring colour; thus the part of the orange next to R, will incline to a red, and that next to Y, to a yellow; and so of the rest.

R E C R E A T I O N XXXIV.

From two or more of the primary colours, to compose others that shall, in appearance, resemble those of the former.

BY mixing the two homogeneous colours red and yellow, an orange will be produced, similar in appearance to that in the series of primary colours; but the light of the one being homogeneous, and, that of the other heterogeneous, if the former be viewed through a prism it will remain unaltered, but the other will be resolved into its component colours, red and yellow. In like manner other contiguous

refraction, and tinge the object with different colours,

ho-

homogeneal colours may compound new colours; as by mixing yellow and green, a colour between them is formed; and if blue be added, there will appear a green that is the middle colour of those three. For the yellow and blue, if they are equal in quantity, will draw the intermediate green equally toward them, and keep it, as it were in equilibrio, that it verge not more to the one than the other. To this compound green there may be added some red and violet, and yet the green will not immediately cease, but grow less vivid; till by adding more red and violet it will become more diluted, and at last, by the prevalence of the added colours, it will be overcome, and turned into whiteness or some other colour.

In like manner if the sun's white, composed of all kind of rays, be added to any homogeneal colour, that colour will not vanish, nor change its species, but be diluted, and by adding more white, it will
become

become continually more diluted. Lastly, if red and violet be mixed, there will be generated, according to their various proportions, various purples, such as are not like in appearance, to the colour of any homogeneous light: and of these purples, mixed with blue and yellow, other new colours may be composed.

RECREATION XXXV.

Out of three of the primary colours, red, yellow, and blue, to produce all the other prismatic colours, and all that are intermediate to them.

PROVIDE, three panes of glass of about five inches square, (see Plate XIII. Fig. 2.) and divide each of them, by parallel lines, into five equal parts.

Take three sheets of very thin paper, which you must paint, lightly, one blue, another yellow, and the third red*. Then

* You must use water colours for this purpose: the blue may be that of Prussia, and very bright;
the

paste on one of the glasses five pieces of the red paper, one of which must cover the whole glass, the second only the four lower divisions, the third the three lower, the fourth the two lowest, and the fifth the last division only. On the other two glasses five pieces of the blue and yellow papers must be pasted in like manner.

You must also have a box of about six inches long, and the same depth and width as the glasses: it must be black on the inside: let one end be quite open, and in the opposite end there must be a hole large enough to see the glasses completely. It must also open at the top, that the glasses may be placed in it conveniently.

When you have put any one of these glasses in the box, and the open end is

the red, carmine; and the yellow gambooge, mixed with a little saffron. These colours must be laid very light and even, on both sides of the paper.

VOL. II.

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turned

turned toward the sun, you will see five distinct shades of the colour it contains.

If you place the blue and yellow glasses together, in a similar direction, you will see five shades of green distinctly formed. When the blue and red glasses are placed, a bright violet will be produced; and by the red and yellow the several shades of orange.

If, instead of placing these glasses in a similar position, you place the side AB of the yellow glass, against the side BD of the blue, (Plate XIII. Fig. 3.) you will see all the various greens that are produced by nature*; if the blue and red glasses be placed in that manner, you will have all the possible varieties of purples, violets, &c. and lastly, if the red and orange

* In the first position of the glasses the quantity of blue and yellow being equal, the same sort of green was constantly visible: but by thus inverting the glasses, the quantity of the colours being constantly unequal, a very pleasing variety of tints is produced.

glasses

glaffes be fo placed, there will be all the intermediate colours, as the marygold, aurora, &c.

R E C R E A T I O N XXXVI.

By means of the three primary colours, red, yellow, and blue, together with light and fhade, to produce all the gradations of the prismatic colours.

ON feven fquare panes of glafs paffe papers that are painted with the feven prismatic colours, in the fame manner as in the laft Recreation. The colours for the orange, green, indigo, and violet, may be made by mixing the other three. Then with biftre*, well diluted, fhade a fhheet of very thin paper, by laying it light on both its fides. With pieces of this paper cover four-fifths of a glafs, of the fame fize with the others, by laying one piece on the four loweft divifions, another on

* The biftre here ufed muft be made of foot, not that in ftone.

the three lowest, a third on the two lowest, and the fourth on the lowest division only: and leaving the top division quite uncovered.

When one of the coloured glasses is placed in the box, together with the glass of shades, so that the side AB of the one be applied to the side BD of the other, as in Fig. 3. of the last Recreation, the several gradations of colours will appear shaded in the same manner as a drapery judiciously painted with that colour.

It is on this principle that certain French artists have proceeded in their endeavours to imitate, by designs printed in colours, paintings in oil: which they do by four plates of the same size, on each of which is engraved the same design. One of these contains all the shades that are to be represented, and which are painted either black, or with a dark grey. One of the three other plates is coloured with blue,
another

another with red, and the third with yellow: each of them being engraved in those parts only which are to represent that colour*, and the engraving is either stronger or weaker, in proportion to the tone of colour that is to be represented†.

These four plates are then passed alternately under the press, and the mixture of their colours produces a print that bears

* When a red drapery is required, it is engraved on the plate assigned to that colour; and so of yellow and blue: but if one of the other colours be wanting, suppose violet, it must be engraved on those that print the red and blue: and so of the rest. The plates of this kind have been hitherto engraved in the manner of mezzotinto, but these, unless they are skilfully managed, soon become smutty. Engravings in the manner of the crayon, would perhaps answer better.

† The principal difficulty in this sort of engraving arises from want of a skilful management, in giving each plate that precise degree of engraving which will produce the tone of colour required. If a bright green is to be represented, there should be an equal quantity of graving on the red and yellow plates: but if an olive green, the yellow plate should be engraved much deeper than the red.

no small resemblance to a painting. It must be confessed, however, that what has been hitherto done of this kind, falls far short of that degree of perfection, of which this art appears susceptible. If they who engrave the best in the manner of the crayon, were to apply themselves to this art, there is reason to expect they would produce far more finished pieces than we have hitherto seen.

RECREATION XXXVII.

The magical prism.

MAKE a hole in the window-shutter of a dark room, through which a broad beam of light may pass, that is to be refracted by the large glass prism *A B C*, (Plate XIII. Fig. 4.) which may be made of pieces of mirrors cemented together, and filled with water.

Provide another prism *D E F*, made of three pieces of wood : through the middle
of

of this there must pass an axis on which it is to revolve. This prism must be covered with white paper, and each of its sides cut through in several places so as to represent different figures, and those of each side should likewise be different. The inside of this prism is to be hollow, and made quite black, that it may not reflect any of the light that passes through the sides into it.

When this prism is placed near to that of glass, as in the figure, with one of its sides EF , perpendicular to the ray of light, the figures on that side will appear perfectly white: but when it comes into the position gh , the figures will appear yellow and red, and when it is in the position kl , they will appear blue and violet. As the prism is turned round its axis, the other sides will have a similar appearance. If instead of a prism a four or five-sided figure be here used, the appearances will be still farther diversified.

This phenomenon arises from the different refrangibility of the rays of light. For when the side EF is in the position *gh*, it is more strongly illuminated by the least refrangible rays, and wherever they are predominant, the object will appear red or yellow. But when it is on the position *kl*, the more refrangible rays being then predominant, it will appear tinged with blue and violet.

RECREATION XXXVIII.

The solar magic lantern.

PROCURE a box, of about a foot high and eighteen inches wide, or such other similar dimensions as you shall think fit; and about three inches deep. Two of the opposite sides of this box must be quite open, and in each of the other sides let there be a groove, wide enough to pass a stiff paper or pasteboard. This box must be fastened against a window on which the sun's rays fall direct. The rest of the window

dow should be closed up, that no light may enter.

Provide several sheets of stiff paper, which must be blacked on one side. On these papers cut out such figures as you shall think proper, and placing them alternately in the grooves of the box, with their blacked sides toward you, look at them through a large and clear glass prism; and if the light be strong, they will appear to be painted with the most lively colours in nature. If you cut on one of these papers the form of the rainbow, about three quarters of an inch wide, you will have a lively representation of that in the atmosphere.

This Recreation may be farther diversified, by pasting very thin papers, lightly painted with different colours, over some of the parts that are cut out: which will appear to change their colours, when viewed through the prism, and to stand out from

from the paper, at different distances, according to the different degrees of refrangibility, of the colours with which they are painted.

For greater convenience, the prism may be placed in a stand on a table, at the height of your eye, and made to turn round on an axis, that when you have got an agreeable prospect, you may fix it in that position. This experiment may be made at a trifling expence; and, if properly conducted, will afford no small entertainment.

R E C R E A T I O N XXXIX.

The artificial rainbow.

OPPPOSITE a window into which the sun shines direct, suspend a glass globe filled with water, by a string that runs over a pulley, so that the sun's rays may fall on it. Then drawing the globe gradually up, when it comes to the height
of

of about forty degrees*, you will see, by placing yourself in a proper situation, a purple colour in the glass, and by drawing it gradually up higher, the other prismatic colours, blue, green, yellow, and red, will successively appear; after which the colours will disappear, till the globe is raised to about fifty degrees, when they will again be seen, but in an inverted order, the red appearing first, and the blue or violet last: and when the globe comes up to little more than fifty-four degrees they will totally vanish.

These appearances serve to explain the phenomena of natural rainbows, of which there are frequently two; the one being about eight degrees above the other, and the order of their colours is inverted, as

* That is if you suppose an arch of a circle to be drawn from the horizon to the zenith, and divided into ninety equal parts or degrees, the globe must be raised to the height of forty of those degrees.

in

in this experiment, red being the uppermost colour in the lower bow, and violet in the other.

The rainbow is not in the clouds, but in the falling rain, and always opposite the sun. The different order of the colours in the bows arises from their different reflections; those of the under bow being caused by two refractions and one reflection, and those of the upper, by two refractions and two reflections, and therefore the colours of this are less bright than the other, their strength being diminished by every reflection.

Now, it has been proved by repeated experiments, that forty degrees forms the greatest angle by which the most refrangible rays can, after one reflection, be refracted to the eye; and that something more than forty-two degrees forms the greatest angle, under which the least refrangible rays can come to the eye after
one

one reflection. Therefore all the colours of the lower bow must lie in the space of less than two degrees. In like manner it has been proved, that fifty degrees make the least angle under which the least refrangible rays can be visible to the eye after two reflections; and that about fifty-four degrees will be the least angle under which the most refrangible rays can come to the eye after two reflections. Therefore all the colours of the upper bow must be in less than four degrees.

It follows from what is here said, that all rainbows are of a circular form and equal magnitude, and as they are always opposite the sun, the parts we see of them must be in proportion to his height above the horizon: when his altitude is forty degrees, only the upper rainbow can be visible, and when it is fifty-four degrees there can be no rainbow: but as the sun's height, during the winter half year, is never equal to forty degrees, there may then be always two bows visible.

R E C R E-

R E C R E A T I O N XL.

The prismatic camera obscura.

MAKE two holes F, f , (Plate XIII. Fig. 5.) in the shutter of a dark chamber, near to each other, and against each hole place a prism $A B C$, and abc , in a perpendicular direction, that their spectrums MN may be cast on the paper in a horizontal line, and coincide with each other; the red and violet of the one being in the same part with those of the other. The paper should be placed at such a distance from the prisms that the spectrum may be sufficiently dilated.

Provide several papers nearly of the same dimension with the spectrum, cross these papers, and draw lines parallel to the divisions of the colours. In these divisions cut out such figures as you shall find will have an agreeable effect, as flowers, trees, animals, &c.

When

When you have placed one of these papers in its proper position, hang a black cloth or paper behind it, that none of the rays that pass through may be reflected, and confuse the phenomenon. The figures cut on the paper will then appear strongly illuminated with all the original colours of nature.

If while one of the prisms remains at rest, the other be revolved on its axis, the continual alteration of the colours will afford a pleasing variety; which may be farther increased by turning the prism round in different directions.

When the prisms are so placed that the two spectrums become coincident in an inverted order of their colours, the red end of one falling on the violet end of the other, if they be then viewed through a third prism *DH*, held parallel to their length, they will no longer appear coincident, but in the form of two distinct spectrums,

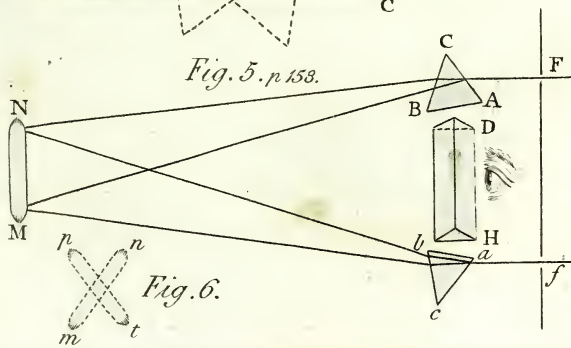
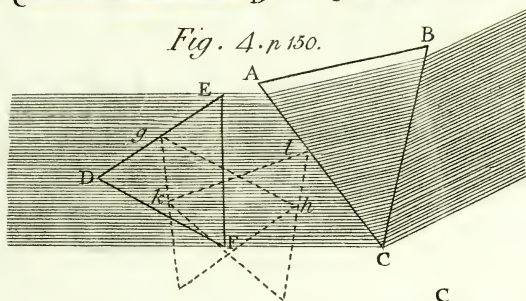
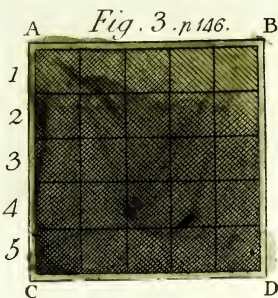
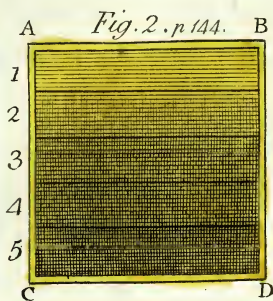
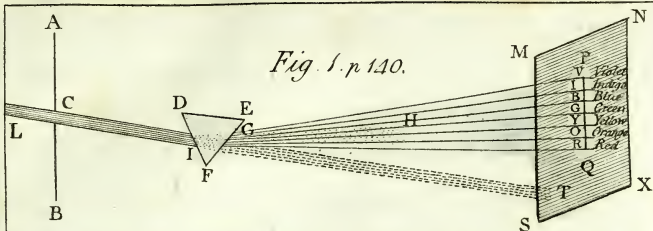
spectrums, pt and nm , (Fig. 6.) crossing one another in the middle, like the letter X. The red of one spectrum and the violet of the other, which were coincident at NM, being parted from each other by a greater refraction of the violet to p and m , than that of the red to n and t .

This Recreation may be farther diversified by adding two other prisms, that shall form a spectrum in the same line, and contiguous to the other; by which not only the variety of figures, but the vicissitude of colours will be considerably augmented.

RECREATION XLI.

The diatonic scale of colours.

THE illustrious Newton, in the course of his sagacious investigations of the properties of light, discovered that the length of the spaces which the seven primary colours possess in the spectrum, exactly corresponds to those of chords
that





that found the seven notes in the diatonic scale of music. As is evident by the following experiment.

On a paper in a dark chamber let a ray of light be largely refracted into the spectrum AFTMGP, (Plate XIV. Fig. 1.) and mark the precise boundaries of the several colours, as *a*, *b*, *c*, &c. Draw lines from those points perpendicular to the opposite side, and you will find that the spaces *M r f F*, by which the red is bounded; *q p d e*, by which the orange is bounded; *p o c d*, by which the yellow is bounded, &c. will be in exact proportion to the divisions of a musical chord for the notes of an octave, that is, as the intervals of these numbers, 1, $\frac{8}{9}$, $\frac{5}{6}$, $\frac{3}{4}$, $\frac{2}{3}$, $\frac{3}{5}$, $\frac{9}{16}$, $\frac{1}{2}$.

R E C R E A T I O N XLII.

Colorific music.

FATHER Castel, a Frenchman, in a curious book he has published on Chromatics, supposes the note *ut* to answer to blue in the prismatic colours, the note *re* to yellow, and *mi* to red. The other tones he refers to the intermediate colours, from whence he constructs the following gamut of colorific music.

Ut	Blue
Ut sharp	Sea-green
Re	Bright green
Re sharp	Olive green
Mi	Yellow
Fa	Aurora
Fa sharp	Orange
Sol	Red
Sol sharp	Crimson
La	Violet
La sharp	Blue violet
Si	Sky Blue
Ut	Blue

This gamut, according to his plan, is to be continued in the same manner for the fol-

following octave; except that the colours are to be more vivid.

He supposes that these colours by striking the eye in the same succession as the sounds, to which he makes them analogous, do the ear, and in the same order of time, they will produce a correspondent sensation of pleasure in the mind. It is on these general principles, which F. Castel has ingeniously dilucidated in his treatise, that he has endeavoured, though with little success, to establish his ocular harpichord.

The construction of this instrument, as here explained, will show that the effects produced by colours by no means answer those of sounds, and that the principle relation there is between them, consists in the duration of the time that they respectively affect the senses.

Between two circles of pasteboard, of ten inches diameter, AB and CD (Plate

XIV. Fig. 2.) enclose a hollow pasteboard cylinder E, eighteen inches long. Divide this cylinder into spaces half an inch wide, by a spiral line that runs round it from top to bottom, and divide its surface into six equal parts by parallel lines drawn between its two extremities ; as is expressed in the figure.

Let the circle A B, at top, be open, and let that at bottom, C D, be closed, and supported by an axis or screw, of half an inch diameter, which must turn freely in a nut placed at the bottom of a box we shall presently describe. To the axis just mentioned adjust a wooden wheel G, of two inches and a half in diameter, and that has twelve or fifteen teeth, which take the endless screw H. Let this cylinder be inclosed in a box I L M N (Fig. 3.) whose base is square, and at whose bottom there is a nut, in which the axis F turns. Observe, that the endless screw H, should come out of the box, that it may receive the

the handle O, by which the cylinder is to be turned.

This box being closed all round, place over it a tin covering, which must be perforated in different parts; from this cover there must hang three or four lights, so placed that they may strongly illumine the inside of the cylinder. In one side of this box (which should be covered with pasteboard) cut eight apertures of half an inch wide, and one-third of an inch high; they must be directly over each other, and the distance between them must be exactly two inches. It is by these openings, which here correspond to the musical notes, that the various colours analogous to them, are to appear; and which being placed on the pasteboard cylinder, as we have shown, are reflected by means of the lights placed within it.

It is easy to conceive, than when the handle O is turned, the cylinder in con-

M 3 sequence

sequence rising half an inch, if it be turned five times round, it will successively show, at the openings made in the side of the box all those that are in the cylinder itself, and which are ranged according to the direction of the inclined lines drawn on it. It is therefore according to the duration of the notes which are to be expressed, that the apertures on the cylinder are to be cut. Observe that the space between two of the parallel lines drawn vertically on the cylinder, is equal to one measure of time, therefore for every turn of the cylinder, there are six measures, and thirty measures for the air that is to be played by this instrument.

The several apertures being made in the side of the cylinder, in conformity to the notes of the tune that is to be expressed, they are to be covered with double pieces of very thin paper, painted on both sides with the colours that are to represent the musical notes.

This

Fig. 1. p. 161.

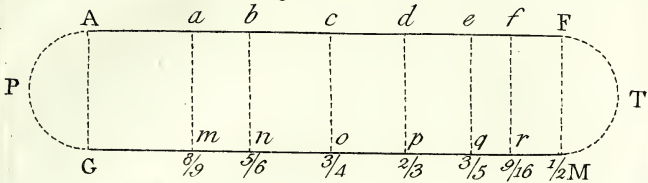
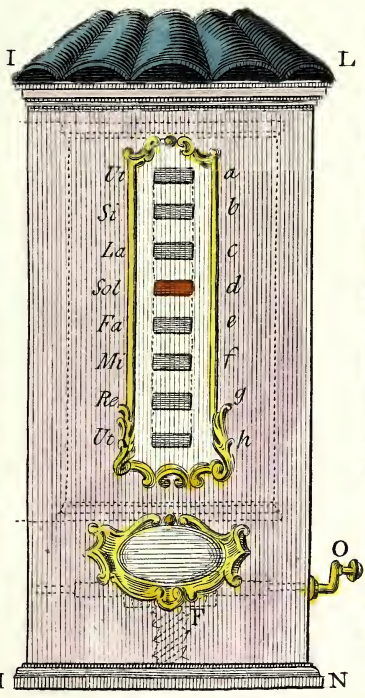
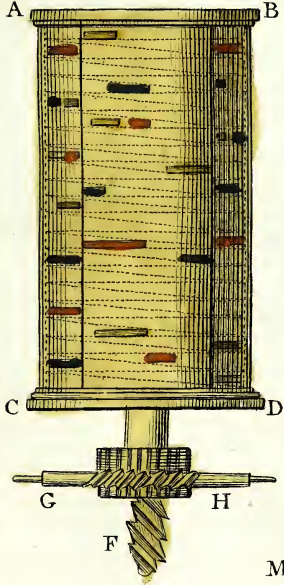


Fig. 3. p. 164.

Fig. 2. p. 163.



This Recreation might be executed in a different manner, and with a much greater extent ; but as the entertainment would not equal the trouble and expence, we have thought it sufficient to give the above piece, by which the reader will be enabled to judge how far the analogy supposed by F. Castel really exists.

This article is taken from M. Guyot, who, though he commends the good father's ingenuity and industry, attributes but little merit to his scheme. Not having seen F. Castel's book, we cannot pretend to judge of the merit of his plan. It is evident, however, from the foregoing Recreation, that there is a much stronger relation between sounds and colours than M. Guyot seems to imagine.

PERSPECTIVE RECREATIONS.

If the following Recreations do not directly belong to optics, they have so great a resemblance to it, that perhaps they could not be introduced any where else with so much propriety.

ANAMORPHOSES.

RECREATION XLIII.

To draw on a plane surface an irregular figure, which, when seen from a proper point of view, will appear exactly similar to a given figure.

ON a paper or pasteboard draw the parallelogram ABCD (Pl. XV. Fig. 1.) of what size you please, provided the sides AB and CD be longer than AC and BD; let it be, for example, four inches long and three wide. Divide it into twelve equal parts, and each of those into four other

other equal parts*. On this parallelogram draw the regular figure that you would have represented, in a distorted form, on the plane.

Draw on a paper the line BA (Fig. 2.) indefinite toward A. Directly over the point B, mark the point of view C, and let fall the perpendicular CB. On the line AB mark the point C, and draw from the point of view C, to that point D, the line CD. On the same line, and at a convenient distance from the point C, draw the line FG, of the same length with AC (Fig. 1.) let it be perpendicular to the line CD, and by which it must be bisected. From the point C to F and G, draw the two lines CF and CG, and continue them till they meet the line AB at the points H and O.

* The smaller the divisions are, the more easy it will be to represent the subjects with precision.

The

The line HO will then appear to the eye C of the same dimension with the line FG , which is equal to the width of the parallelogram $ABCD$, as must necessarily follow from the principle laid down in the part of Optics; that is, because both these lines appear under the same angle HCO .

Then divide the line FG into the same number of parts with the side of the parallelogram AC , (Fig. 1.) and from the point of view C , to the line AB , draw the lines CI , CL , CM , CN , through the divisions in the line FG .

On another paper draw the line AB (Fig. 3.) equal to the line CA , (Fig. 2.) and at its extremity B , erect the indefinite perpendicular BC . From the point B of the line AB to the point E , in the same line, set off a space equal to the line CF , (Fig. 2.) At the point E , divide the line AB by the perpendicular HI , equal to CD ,

CD, (Fig. 1.) that is, equal to the length of the parallelogram. This line must also be divided into two equal parts by the line AB.

From the point B to the points H and I, draw the lines BH and BI, and continue them towards C and D. Take the distances that are between H and I, LD, M and N, (Fig. 2.) and transpose them to the line AB (Fig. 3.) from A to I, L, M, N, O, and draw the lines Y, Z, perpendicular to each of these divisions. Divide the line CD into eight equal parts, and draw the lines BG, BQ, BR, BS, BT, and BV.

- These divisions being made, the trapezium CHDI will be divided into as many parts as the parallelogram ABCD, (Fig. 1.) and all these divisions, though of themselves irregular, will appear to the eye, when placed at the point C, (Fig. 2.) of the same

same figure and magnitude as the parallelogram: all the lines that form the divisions included in the trapezium *CHDI* being seen under similar angles. In order to facilitate the transposing the several parts of the design contained in the parallelogram, to the trapezium, it will be proper to number the principal divisions. The whole, moreover, should be traced with great precision*. Observe, that all the right lines in the parallelogram form as many right lines in the trapezium, therefore when you have marked their extremities, you may draw them with a ruler from one point to the other. With regard to curve lines, you will judge of their direction by the points where they cut the divisions of the parallelograms, and trans-

* This method of drawing an irregular figure is taken from M. Guyot, and differs from those that are given by Nicéron and Ozanam, as it appears more exact to place the design that is to be represented in such manner that the ray, or principal point of view, may fall perpendicular on the center of the supposed picture placed at *FG*.

pose them to the corresponding divisions of the trapezium.

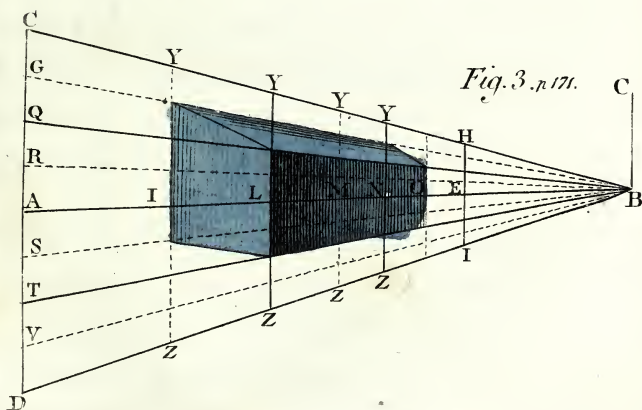
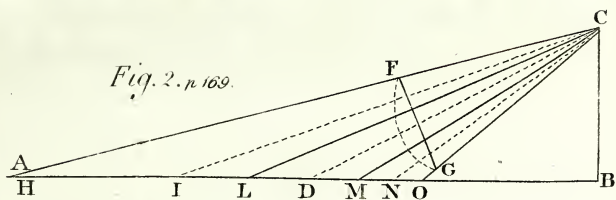
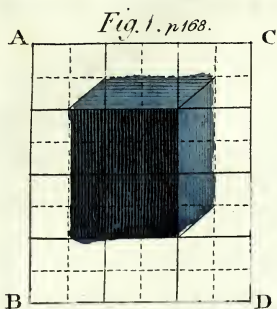
Note, Care must be taken that the paper on which the distorted figure is drawn be well stretched on a plane, that its surface may be quite even. You should also examine it attentively from the point of view; and for that purpose it will be convenient to have a little circle of brass, through which a hole of about two tenths of an inch is made, and placed upon a stand (see Fig. 4.) By that overture this piece of perspective illusion will produce an agreeable surprize.

Observe that the distance of the point of view from the picture may be taken at pleasure, provided it be not less than its width. When the point of view is near the picture it appears more deformed than when it is at a greater distance, for the parts then become more extended toward CD; from whence it follows, that if we
would

would execute a design of this sort on the side of a gallery, it must be regulated according to the dimensions of the part on which it is to be drawn. These subjects, when well executed, at full length, are highly agreeable, and appear the more extraordinary, as the eye not being able to view them but by parts, (when walking in the gallery*) we cannot form the least idea of what they will present when seen from a proper point of view, where the effect is truly admirable.

* There are, at the convent of Minims in the Palace Royale at Paris, several subjects of this kind, painted on the walls of the cloister by P. Nicéron, who has published an excellent treatise on this art. Among others, the figure of a Magdalen daily excites the curiosity of a number of connoisseurs. Unfortunately, these pieces, which have suffered by time, have not been properly repaired.

R E C R E-





RECREATION XLIV.

To draw an irregular figure on a plane, which being seen from two opposite points of view, shall represent two different regular objects.

MAKE choice of a plane of convenient size, suppose two feet long and half a foot wide. Draw the line AB of the same length, (Plate XVI. Fig. 1.) continue it on each side to C and D , and erect the perpendiculars CF and DG to the height of about three inches. Draw the lines AF and BG , and divide the line AB into six equal parts at the points S , or into any other number you shall think fit. From the two points of view F and G draw the lines FS and GS , to those six divisions.

Then on the line GA set off the distance GB , and on the line FB the distance FA , and draw the two lines BH and AI , which will determine the width of the two subjects

jects you are to represent on the plane, and are to be viewed, the one from the point F, and the other from G; and of which the unequal divisions formed by the lines GS and FS, will determine those that are to correspond to the separate and inclined parts of the irregular figure which is to be seen from the points of view F and G.

This first preparation being made, draw the parallelogram ABCD (Fig. 2.) of the same length with the line AB in the preceding figure, and about six inches wide: divide it into two equal parts by the line FG, which continue to H and I, equal to the distance there is between CA and DB (Fig. 1.)

From the points AOSB (Fig. 1.) let fall the perpendiculars AA, OL, SL, and BC, on the line AC (Fig. 2.) and from the points L draw the lines LM parallel to AB.

From

From the four angles of the parallelogram ABCD, draw the lines AI and BI to the point of view I, and those of CH and DH to the other point of view H; these lines will determine by the sections at X and Y the apparent height of the figure.

Then divide the lines AB and CD, into as many equal parts as you shall think proper, and from those points draw the lines NI and NH.

Next, draw on a paper the two parallelograms FGHI, LMNO, (Fig. 3.) and on them you are to draw the two different designs that you would represent in the distorted figure. Let each of these parallelograms be of an equal height with the distance XY, (Fig. 2.) and of the same length as HB (Fig. 1.) Divide their height FH or LN, according to the divisions of the line XY (Fig. 2.) and their length HI or NO, according to those of the line BH (Fig. 1.)

After having drawn the two designs, as correctly as possible, on the divisions just mentioned, take a board or pasteboard ABCD (Fig. 4.) of the same dimensions with the parallelogram ABCD, (Fig. 2.) and on it draw the lines LM, corresponding to the perpendiculars let fall from OS. (Fig. 1.) These lines should be drawn sufficiently deep to admit the folds of paper hereafter mentioned.

Take a very thin paper ABCD (Fig. 5.) of about two feet and a half long, and six inches wide, and on it draw parallel lines, at distances corresponding to A O, O S, S O, &c. (Fig. 1.) which you will measure with a compass from the angles on the line AB (Fig. 1.)

Divide this paper into two equal parts by a line drawn from the points X and Y, and observe that it is on the spaces *b, b, b*, &c. that you are to draw the irregular figure which is to be seen from the point F; and

and on those of c, c, c , &c. that which is to be seen from the point G .

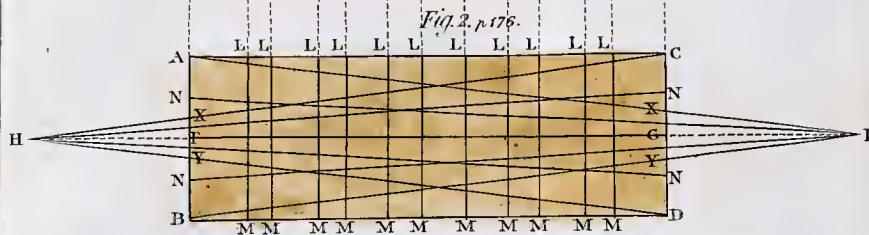
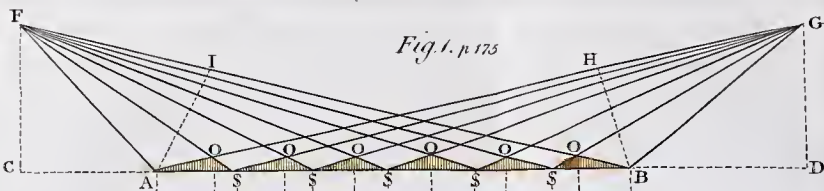
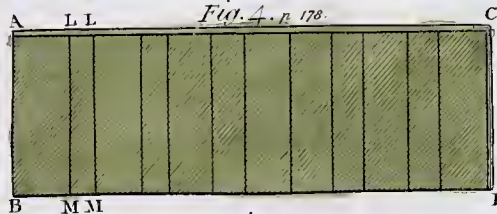
On each of these spaces draw the lines, not punctuated, of the parallelogram $ABCD$ (Fig. 2.) that terminate in the points H and I . Then trace on the same paper all the strokes of the two figures drawn on the two parallelograms, (Fig. 3.) carefully observing the several divisions to which they correspond.

When this irregular figure is quite finished, fold the paper according to the divisions that have been drawn on it, so that each of the divisions S , may turn one way, and each of the divisions O , the other way, and paste the whole on a board, in such a manner that the folds made on the blank side of the paper, may answer to the lines traced in the board. On the paper thus pasted lay something that may keep it in proper form till the paste is dry. Then let it be so placed that six of its divisions

may be opposite to each of the points of view F and G.

To distinguish the objects on the parallelogram with greater precision, you must have (as in the foregoing Recreation) two little circles, with a small hole in each, and place them exactly on the points of view that have been fixed. The eye being then placed at either of those points, will discern the regular figure ; but when the scheme is viewed in front, it presents a form so distorted that it is impossible to conjecture what it is intended to represent.

Observe, This design differs in the construction from that in the first Recreation ; as here, the divisions drawn on the irregular figure regulate those of the two other figures. It is indeed more difficult, but then it is also more entertaining ; and with a little application it may be easily executed, as nothing more is necessary than
to

*Fig. 3. p. 177.**Fig. 4. p. 178.**Fig. 3. p. 177.**Fig. 5. p. 178.*

to transfer the divisions carefully from one figure to the other.

To perform this sort of anamorphosis with more celerity, you may draw the plan on a pasteboard, and placing a transparent paper over it, trace the subject thereon ; the same pasteboard will serve to execute, equally well all sorts of subjects.

RECREATION XLV.

To draw on the base of a cone, an irregular figure, which shall appear, when seen from a proper point of view, not only regular, but elevated above the surface of the cone.

THE geometric method that might be here given for drawing the figure proposed, being extremely tedious and difficult, on account of the various curves that it is necessary to draw on the base of the cone, we shall here describe a more simple method, by making use of a lamp. This method may likewise be used in the

drawing distorted subjects on all irregular surfaces, whatever their figure may be.

Let E F G (Plate XVII. Fig 1.) be the cone, on the basis of which a distorted figure is to be drawn, that being viewed from the point H, shall appear regular; and exactly resembling that which is placed at N M. Place the cone in a circular overture made in the board ABCD, which should be supported by four feet, that the point of the cone may not touch the table on which it stands. Fix at the end of the board an upright piece I, that is to hold a small circle of brass, through which is made a hole H, of two tenths of an inch in diameter, that serves for the point of view.

Prepare a lamp as A, (Fig. 2.) the light of which may be raised or lowered at pleasure, and to which is fixed a brass arm BC, bearing a sort of funnel D, in the shape of a truncated cone, and whose opening

ing at the end next the light is not more than three or four tenths of an inch in diameter.

Draw the subject you would represent on the base of the cone, on a piece of glass of equal height with the space MN*, that is of the apparent height of the diameter EF, of the base of the cone when seen from the point H ; place it perpendicular on the board at the point F, that is, at the extremity of the cone.

These preparations being made, take away the piece that bears the point of view H, and place the lamp, so prepared in such manner that the light may be exactly where the point H was. Its rays then passing through the glass at MN, will en-

* It must be drawn with a very light stroke, and you must make use of a colour that is quite opaque.

lighten all the lower surface of the cone, and there shew, in a distorted form, the subject that is painted on the glass.

Then draw with a pencil all the strokes of the shadow that are on the cone ; and taking away the light, place the point of view H, and see if what you have drawn correspond with the subject on the glass, correcting what imperfections there may chance to be. In the last place, colour the subject so traced on the cone, with the utmost attention, inspecting your work from time to time from the point of view, before you give it the finishing strokes.

When the figure that is drawn and painted on the base of the cone is viewed from the point H, it appears to be at the same point where the glass M N was placed, and in the same form that it was painted on that glass. The eye even perceives it above the surface of the board in which the cone is placed,
and

and thereby receives a remarkable and pleasing illusion.

Note. This manner of drawing distorted figures by means of a lamp and transparent glass, may be advantageously used for all irregular figures, that are difficult to draw geometrically. The subjects that are drawn on the glass may also be shaded and coloured, in the same manner as for the camera obscura; in order to have the appearance of colours on the distorted picture.

If a circle be described on paper or pasteboard, and placed firm upon the table, where the cone is supposed to be, it will have precisely the same effect.

R E C R E A T I O N XLVI.

To draw, easily and correctly, a landscape or any other object, without being obliged to observe the rules of perspective, and without the aid of the camera obscura.

PROCURE a box of pasteboard ABCD (Plate XVII. Fig. 3.) of about a foot and a half long, and made in the shape of a truncated pyramid, whose base BDFG is eight inches wide, and six inches high. Fix to the other end of it a tube of four or five inches long, and which you can draw out from the box more or less. Line the inside of the box with black paper, and place it upon a leg or stand of wood H, and on which it may be elevated or depressed by the hinge I.

Take a small frame of wood ABCD (Fig. 4.) and divide it at every inch by lines of black silk drawn cross it, forming forty-eight

eight equal parts; divide these into still smaller equal parts, by lines of finer filk*: fix this frame at the end B D, as the base of the pyramid.

Provide a drawing paper, divided into the same number of parts as is the frame, by lines lightly drawn in chalk. It is not material of what size these divisions are; that will depend entirely on the size you propose to draw the objects by this instrument.

Place this instrument opposite a landscape, or any other object that you want to draw, and fix the leg firmly on, or in the ground, that it may not shake: then turning it to the side you choose, raise or incline it, and put the tube farther in or out, till you have gained an advantageous view of the object you intend to draw.

* The different size of the filk serves to distinguish more readily the corresponding divisions.

Place

Place yourself by the instrument*, which you have adjusted to the height of your eye, and looking through the tube, carefully observe all that is contained in each division of the frame, and transpose it to the corresponding division in your paper: and if you have the least knowledge in painting, or even drawing, you will make a very pleasing picture, and one in which all the objects will appear in the most exact proportion.

Note. By the same method you may draw all sorts of objects, as architecture, views, &c. and even human figures, if they remain some time in the same attitude, and are at a proper distance from the instrument.

* You may provide yourself with one of those stools that fold up, and are easily portable.

RECREATION XLVII.

Illuminated prospects.

PROVIDE yourself with some of those prints that are commonly used in optical machines, printed on very white and very thin paper; taking care to make choice of such as have the greatest effect from the manner in which the objects are placed in perspective. Paste one of these on the borders of a frame, and paint it carefully with the most lively colours, making use of none that are terrestrial. Observe to retouch those parts several times where the engraving is strongest*, then cut off the upper part or sky, and fix that on another frame.

The prints being thus prepared, place them in a box ABCD (Plate XVII. Fig. 5.)

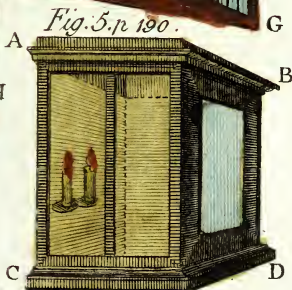
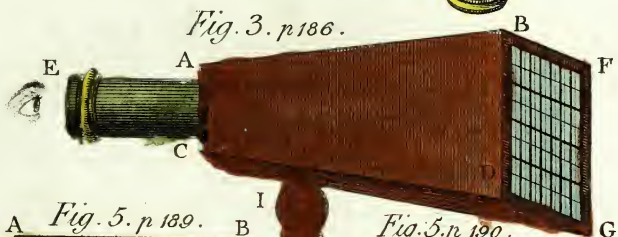
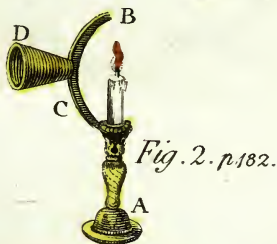
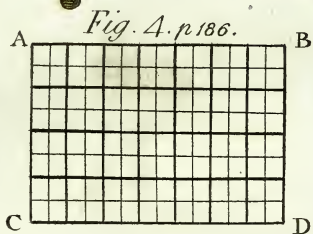
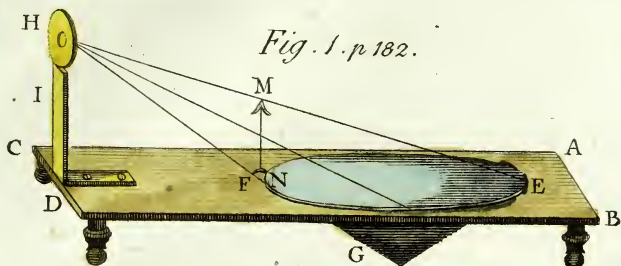
* When you colour a print, place it against a plate of glass, in an erect position before you, that it may be enlightened by the sun. You may also colour both sides of the print.

the

the opening to which E F G H, should be a little less than the print. Cover this opening with a glass, and paint all the space between it and the prints, which should be about two or three inches, black. The frame that contains the sky should be about an inch behind the other. In the back part of this box, which is behind the prints, and which may be about four inches deep, place four or five small candlesticks to hold wax lights, and cover that part entirely with tin, that it may be the more luminous.

When the print is placed between the wax lights and the opening in the front of the box, and there is no other light in the room, the effect will be highly pleasing; especially if the lights are at a sufficient distance from each other, and not too strong, that they may not occasion any blots in the print. Those prints that represent the rising or setting of the sun will have a very picturesque appearance.

Such





Such as represent conflagrations have also a striking effect.

Note. There should be two grooves for the print next the glass, that you may insert a second subject before you draw away the first: and that the lights in the back of the box may not be discovered.

You must not, thinking to make the print more transparent, cover it with varnish: for that will prevent the degradation of the colours from being visible. The frame should enter the side of the box by a groove, that a variety of subjects may be introduced.

R E C R E A T I O N XLVIII.

Transparent illuminations.

THE box that is to enclose these subjects may be made in the same manner with that of the preceding Recreation, only observing that it will be proper to augment

ment the number of lights, and employ such prints as are agreeable to the subject.

With a very small circular tool you are to cut out all the places where the light is intended to appear, or where it is expressed, if the print represent an illumination. Particular care must be had to make use of the finest tools in those parts of the print that are intended to appear at the greatest distance.

These prints must by no means be transparent, like those in the preceding Recreation; on the contrary, they should be printed on a thick paper, or rather it should be doubled, that very little of the engraving may appear. Behind the print must be placed a very fine transparent paper, varnished, fixed on a frame, and lightly painted with a deep yellow, or saffron colour, which must be laid on thickest at those places that are opposite the parts of the print that are to appear at the greatest distance.

The

The setting of the sun, succeeded by a night scene, may be very pleasingly represented in this method. Thus: procure a landscape, in which is the figure of the setting sun, illuminated as above described. Let the bottom of this scene rest upon an upright board in the box, of about two or three inches high, and let it be gradually moved off that board, and lowered down to the bottom of the box, on the side next the glass, by which means the sun will appear to descend. Let the lights then be gradually withdrawn: and change the first landscape for a night scene, with the moon and stars, properly perforated. The yellow paper must be changed for one that is white and transparent, and the lights be again introduced, when the moon, stars, and other illuminated parts will appear in their natural form. For the more easy removing of the lights they may be all placed upon one stand, but at different distances.

This piece of illumination might also be put into the common optical machine; but the magnifying glass there used considerably enlarging the object, the light reflected by the cut and transparent parts, then becomes greatly weakened, as it takes up a much larger space; and that greatly diminishes the vivacity which is necessary to imitate nature, and to produce the illusion. If, however, you are desirous of viewing this piece by the magnifier, you must take away the inclined mirror which is placed in those sort of optical machines, and place the transparent picture or print in the front of the glass; or otherwise it will be scarce possible to render it luminous, except by reflection, which affords but a very feeble light.

A C O U S T I C S.

THE science of acoustics instructs us in the nature of sound. It is divided by some writers into diacoustics, which explains the properties of those sounds that come directly from the sonorous body to the ear ; and catacoustics, which treats of reflected sounds : but such distinction does not appear to be of any real utility.

D E F I N I T I O N S.

1. Sounds are either acute or grave, simple or compound.
2. Those sounds that are shrill or sharp are called acute : and
3. Those that are deep or hollow, are called grave sounds.
4. A simple sound is that produced by a single stroke on a sonorous body ; and compound sounds are those that proceed from several bodies struck at the same time, or from several strokes on different parts of the same body.

5. A chord is a string of catgut, brass wire, &c. so stretched as when struck to yield a distinct sound.

6. A vibration is the regular, alternate motion of bodies, by which, when put out of their natural state, they endeavour to return to it. Thus the string AB (Pl. XVIII. Fig. 1. being forced out of its natural position to that of A c B, vibrates to *d*, and then to *e*, *f*, *g*, &c. till it returns to its first state at A B.

A P H O R I S M S.

1. All sound is produced by an undulatory or wave-like motion of the air*, excited by the vibrations of a sonorous body proceeding from a stroke of some other body.

2. Acute sounds arise from quick vibra-

* That air is the medium of sound is evident from a bell placed in the receiver of an air-pump, which may be heard to a considerable distance before the air is exhausted, but after can scarce be distinguished when quite near.

tions of the parts of a body, and grave sounds from slow vibrations.

3. Smooth and clear sounds proceed from bodies that are homogeneous, and of an uniform figure ; and harsh or obtuse sounds, from such as are of a mixed matter and irregular figure.

4. In bodies of a similar figure and dimension, and of equal elasticity, their tones are equal to their densities : the denser the body the graver is the tone ; therefore a bar of gold must have a graver sound than one of silver, of equal dimensions ; supposing them to be of equal elasticity.

5. If two bodies are composed of the same matter, and are of similar figure, their tones will be in proportion to the quantities of matter. Thus, the tones of two globes of brass will be to each other in proportion to their diameters.

6. The vibrations of chords is in proportion to their lengths, diameters, and tension.

7. All the vibrations of the same chord, as A *c* B, (Plate XVIII. Fig. 1.) A *d* B, A *e* B, &c. are made in the same time.

8. if two chords are of the same diameter or thickness, and equally stretched, their vibrations, in the same time, will be in proportion to their lengths inversely, that is, a chord of six inches will make two vibrations while a chord of twelve inches makes one*.

9. If two chords frequently vibrate together they produce a concord; and the more frequent the coincidence of vibration, the more pleasing the concord.

* From hence we learn how to divide any chord so that it may sound the seven concords: as thus, divide the line AB (Plate XVIII. Fig. 2.) into two equal parts in C, and CB into two equal parts at D, and CD into two equal parts at E. Then AC will be to AB as $\frac{1}{2}$ that is, an octave; AC to AD as $\frac{2}{3}$, a fifth; AD to AB as $\frac{3}{4}$, a fourth; AC to AE as $\frac{4}{5}$, a third greater; AE to AD as $\frac{5}{6}$, a third lesser; EB to AE as $\frac{3}{5}$, a sixth greater; and AE to AB as $\frac{5}{8}$, a sixth lesser.

10. Sound is propagated in concentric circles every way round the sonorous body*.

11. All sounds, whether great or small, are of equal velocity.

12. The space passed over by sound is constantly equal in equal times, whether it come from a greater or less distance.

13. The motion of sound is at the rate of 1142 feet in a second, and no obstacles obstruct its progress; a contrary wind only a small matter diminishing its velocity†.

* The distance to which sounds may be heard is very great. Authors of credit relate that the sound of cannon has been heard 180 and 200 miles.

† By this axiom we are enabled to find the distance between the objects that would be otherwise immeasurable. For example, suppose you see the flash of a gun in the night at sea, and tell seven seconds before you hear the report, it follows therefore, that the distance is seven times 1142 feet; that is twenty-four yards more than a mile and a half. In like manner if you observe the number of seconds between the lightning and the report of the thunder, you know the distance of the cloud from whence it proceeds.

14. The velocity of sound is to that of a brisk wind as fifty to one.

15. The strength of sounds is greatest in cold and dense air, and least in that which is warm and rarefied.

16. In all sounds the angle of incidence is equal to that of reflection, that is, if a line be drawn perpendicular to the reflecting surface, the point from which the sound issues, and that to which it is reflected, will be equally distant from the perpendicular line.

RECREATION XLIX.

The Æolipiles.

AN æolipile is a small globe of brass or other metal, into which a slender neck or pipe is inserted. This ball, when made red hot, is cast into a vessel of water, which will rush into its cavity, then almost void of air. The ball being then set on the fire, the water, by the rarefaction of the internal air, will be forced out in steam, by fits, with great violence, and with a strange noise.

If to the necks of two or more of these æolipiles there be fitted those calls that are used by fowlers and hunters, and the æolipiles be then placed privately on the fire; as the steam rushes forth they will make such a horrible noise, that a person who is ignorant of the contrivance cannot fail being greatly astonished.

Great

Great care should be taken that the neck of the æolipile be not stopped when it is placed on the fire, for in that case it would burst, and might do no small mischief.

R E C R E A T I O N L.

The communicative busts.

LET there be two heads of plaster of Paris, placed on pedestals, on the opposite sides of a room. There must be a tin tube of an inch diameter, that must pass from the ear of one head, through the pedestal, under the floor, and go up to the mouth of the other. Observe, that the end of the tube which is next the ear of the one head, should be considerably larger than that end which comes to the mouth of the other. Let the whole be so disposed that there may not be the least suspicion of a communication.

Now, when a person speaks, quite low, into the ear of one bust, the sound is reverber-

verberated through the length of the tube, and will be distinctly heard by any one who shall place his ear to the mouth of the other. It is not necessary that the tube should come to the lips of the bust. If there be two tubes, one going to the ear, and the other to the mouth of each head, two persons may converse together, by applying their mouth and ear reciprocally to the mouth and ear of the busts; and at the same time other persons that stand in the middle of the chamber, between the heads, will not hear any part of their conversation.

R E C R E A T I O N LI.

The oracular head.

PLACE a bust on a pedestal in the corner of a room, and let there be two tubes, as in the foregoing Recreation, one of which must go from the mouth and the other from the ear of the bust, through the pedestal, and the floor, to an under apartment.

partment. There may be likewise wires that go from the under jaw, and the eyes of the bust, by which they may be easily moved.

A person being placed in the under room, and at a signal given applying his ear to one of the tubes, will hear any question that is asked; and immediately reply, moving at the same time the mouth and the eyes of the bust, by means of the wires.

R E C R E A T I O N LII.

A solar sonata.

IN a large case, such as is used for dials and spring clocks, the front of which, or at least the lower part of it, must be of glass, covered on the inside with gauze, let there be placed a barrel organ, which, when wound up, is prevented from playing, by a catch that takes a toothed wheel at the end of the barrel. To one end of
this

this catch there must be joined a wire, at the end of which there is a flat circle of cork, of the same dimension with the inside of a glass tube, in which it is to rise and fall. This tube must communicate with a reservoir that goes across the front part of the bottom of the case, which is to be filled with spirits, such as is used in thermometers, but not coloured, that it may be the better concealed by the gauze.

This case being placed in the sun, the spirits will be rarefied by the heat, and rising in the tube, will lift up the catch or trigger, and set the organ in play ; which it will continue to do as long as it is kept in the sun ; for the spirits cannot run out of the tube, that part of the catch to which the circle is fixed being prevented from rising beyond a certain point, by a check placed over it. Care must be taken to remove the machine out of the sun before the organ runs down, that its stopping may be evidently effected by the cold.

When

When the machine is placed againſt the ſide of a room on which the ſun ſhines ſtrong, it may conſtantly remain in the ſame place, if you incloſe it in a ſecond caſe, made of thick wood, and placed at a little diſtance from the other. When you want it to perform, it will be only neceſſary to throw open the door of the outer caſe, and expoſe it to the ſun.

But if the machine be moveable, it will perform in all ſeaſons by being placed before the fire; and in the winter it will more readily ſtop when removed into the cold.

A machine of this fort is ſaid to have been invented by Cornelius Dreble, in the laſt century. What the conſtruction of that was we know not; but might very likely be more complex, but could ſcarce anſwer the intention more readily.

R E C R E-

RECREATION LIII.

An automatus harpsichord.

UNDER the keys of a common harpsichord let there be fixed a barrel, something like that in a chamber organ, with stops or pins corresponding to the tunes you would have it play. These stops must be moveable, so that the tunes may be varied at pleasure. From each of the keys let there go a wire perpendicular down; the ends of these wires must be turned up for about one-fourth of an inch. Behind these wires let there be an iron bar, to prevent them from going too far back. Now, as the barrel turns round, its pins take the ends of the wires, which pull down the keys, and play the harpsichord. The barrel and wires are to be all enclosed in a case.

In the chimney of the same room where the harpsichord stands, or at least in one adjacent,

adjacent, there must be a smoke jack, from whence comes down a wire, or cord, that, passing behind the wainscot adjoining the chimney, goes under the floor, and up one of the legs of the harpsichord into the case, and round a small wheel fixed on the axis of that first mentioned. There should be pullies at different distances, behind the wainscot and under the floor, to facilitate the motion of the chord.

This machinery may be applied to any other keyed instrument, as well as to chimes, and to many other purposes where a regular continued motion is required.

An instrument of this sort may be considered as a perpetual motion, according to the common acceptation of the term, for it will never cease going till the fire be extinguished, or some parts of the machinery be worn out.

R E C R E -

RECREATION LIV.

A ventosal symphony.

AT the top of a summer-house, or other building, freely exposed to the wind, let there be fixed the wings, or compounded vane AB (Pl. XVIII. Fig. 3.) on which is the pinion C, that takes the toothed wheel D, fixed on the axis EF, which at its other end carries the wheel G, that takes the pinion H. All these wheels and pinions are to be between the roof and the ceiling of the building. The pinion H is fixed to the perpendicular axis IK, which goes down very near the wall of the room, and may be covered after the same manner as are bell wires. At the lower end of the axis IK there is a small pinion L, that takes the wheel M, fixed on the axis of the great wheel N.O. In this wheel there must be placcd a number of stops, corresponding to the tunes it is to play. These stops are to be moveable that the tunes may be altered at pleasure. Against this

VOL. II. P wheel

wheel there must hang twelve small bells, answering to the notes of the gamut. Therefore, as the wheel turns round, the stops striking against the bells, play the several tunes. There should be a fly to the great wheel, to regulate its motion when the wind is strong. The wheel NO, and the bells are to be enclosed in a case.

There may be several sets of bells, one of which may answer to the tenor, another to the treble, and a third to the base; or they may play different tunes, according to the size of the wheel. As the bells are small, if they are silver, their tone will be the more pleasing.

Instead of bells, glasses may be here used, so disposed as to move freely at the stroke of the stops. This machinery may likewise be applied to a barrel-organ; and to many other uses.

RECREATION LV.

The nocturnal reveilleur.

A GAINST the wall of a room, near the ceiling, fix a wheel of 12 or 18 inches diameter ; on the rim of which place a number of bells in tune, and, if you please, of different sizes. To the axis of this wheel there should be fixed a fly to regulate its motion ; and round the circumference there must be wound a rope, to the end of which is hung a weight.

Near to the wheel let a stand be fixed, on which is an upright piece that holds a balance or moveable lever, on one end of which rests the weight just mentioned, and to the other end must hang an inverted hollow cone, or funnel, the aperture of which is very small. This cone must be graduated on the inside, that the sand put

in may answer to the number of hours it is to run. Against the upright piece, on the side next the cone, there must be fixed a check, to prevent it from descending. This stand, together with the wheel, may be enclosed in a case, and so contrived as to be moved from one room to another with very little trouble.

It is evident from the construction of this machine, that when a certain quantity of the sand is run out, the weight will descend, and put the wheel in motion, which motion will continue till the weight comes to the ground. If the wheel be required to continue longer in motion, two or more pullies may be added, over which the rope may run.

The size of the bells should be adapted to the soniferous disposition of the party they are intended to rouse: or if you please, a drum or tabor may be added,
the

the stick to which may be fixed in the side of the room, by a swivel that goes through the middle of it ; and one end of it being lifted up by teeth placed on the circumference of the wheel, the other end will alternately strike the drum.

R E C R E A T I O N LVI.

A musical cascade.

WHERE there is a natural cascade, near the lower stream, but not in it, let there be placed a large wheel, equal to the breadth of the cascade: the diameter of this wheel, for about a foot from each end, must be much less than that of the middle part; and all the water from the cascade must be made to fall on the ends*. The remaining part of the wheel which is to be kept free from the water, must consist of bars, on which are placed stops that strike against the bells, as in the 54th recreation: these stops must likewise be moveable, but larger than in that Recreation, as well as the bells, that they may be heard much farther. It is evident

* The water that falls on the wheel may pass thro' pipes, so that part of it may be made occasionally to pass ever or fall short of the wheel, as you would have the time of the music quicker or slower.

from

from the construction of this machine, that the water falling on the floats at the ends of the wheel, will make the stops, which are adapted to different tunes, strike the notes of those tunes on the respective bells. Two or three sets of bells may here be placed on the same line, when the cascade is sufficiently wide.

Where there is not a natural cascade, one may be artificially constructed, by raising part of the ground, wherever there is a descent of water ; whether it be a stream that supplies a reservoir or fountain, or serves domestic uses ; or if it be refuse water that has already served some other purpose.

R E C R E A T I O N LVII.

Reverberated sounds.

SOUND, like light, after it has been reflected from several places, may be collected in one point, as in a focus ; and it will be there more audible than in any other part, even than at the place from whence it proceeded. On this principle it is that a whispering gallery is constructed.

The form of this gallery must be that of a concave hemisphere*, as ABC (Pl. XVIII. Fig. 4.) and if a low sound or whisper be uttered at A, the vibrations expanding themselves every way will impinge on the points DDD, &c. and from thence be reflected to EEE, and from thence to the points F and G, till at last they all meet

* A cylindric or elliptic arch will answer still better than one that is circular.

in C, where, as we have said, the sound will be the most distinctly heard.

Upon this principle also it is that the speaking trumpet is formed. For the sound, in passing through the long and narrow part of the tube, is continually reflected from its curved side into the axis, and by that mean is prevented from spreading till at its exit from the tube, whereby the strength of the sound is greatly increased.

As by the last aphorism, page 200, the angle of reflected sound is equal to that of its incidence, if we know the point from which any sound proceeds, and the place from which it is reflected, we may easily find the point in which its echo will be heard.

To hear the echo of one syllable, we must be at the distance of 120 feet from the reflecting surface: for two syllables, 240 feet; for three syllables 360 feet, &c.

For

For when we speak distinctly we scarce pronounce more than three or three syllables and a half in a second; and as by aphorism 13, sound goes 1142 feet in a second, if the distance between the speaker and the reflecting surface were less than 360 feet, the first syllable would be returned before the last was pronounced*, and therefore the echo could not be distinctly heard. The echo in Woodstock Park is said to return 17 syllables in the day, and 20 in the night: for then the air being colder and denser, by aphorism 15, the strength of the sound must be greater. From hence we may determine nearly, the distance of an object that is inacces-

* According to the aphorism, the distance should be 380 feet; for the first syllable must go as far as is equal to the time the two last syllables are pronouncing, that is, two-thirds of a second; therefore the distance should be equal to two-thirds of 1142 feet, or $760\frac{2}{3}$, that is, $380\frac{1}{3}$ going and coming. But as some time must be allowed for the reflecting surface to be made to vibrate by the impinging sound, the first distance, 360 feet, will be very near the truth.

fible;

fible ; for if an echo of 10 syllables be reflected from the side of a church or tower, it follows, from what has been said, that the object must be 1200 feet distant.

The same sound may have several echoes, if there be several reflecting surfaces so disposed as to make it reverberate to the same point. Thus a violin or other instrument, when sounded in a room where there are several arches of the same form, will sound like a number of violins of the same size playing in concert : or if the arches be of different forms, there will seem to be different instruments playing the same tune.

R E C R E -

R E C R E A T I O N LVIII.

The converseive statue.

PLACE a concave mirror of about two feet diameter, as AB* (Plate XVIII. Fig. 5.) in a perpendicular direction. The focus of this mirror may be at 15 or 18 inches distance from its surface. At the distance of about five or six feet let there be a partition, in which there is an opening EF, equal to the size of the mirror; against this opening must be placed a picture, painted in water-colours, on a thin cloth, that the sound may easily pass through it †.

* Both the mirrors here used may be of tin or gilt pasteboard, this experiment not requiring such as are very accurate.

† A Recreation of this kind may be performed in a field or garden, between two hedges, in one of which the mirror AB may be placed, and in the other an opening artfully contrived. The more effectually to conceal the cause of this illusion,

Behind the partition, at the distance of two or three feet, place another mirror GH, of the same size as the former, and let it be diametrically opposite to it.

At the point C let there be placed the figure of a man seated on a pedestal, and let his ear be placed exactly in the focus of the first mirror; his lower jaw must be made to open by a wire, and shut by a spring; and there may be another wire to move the eyes; these wires must pass through the figure, go under the floor, and come up behind the partition.

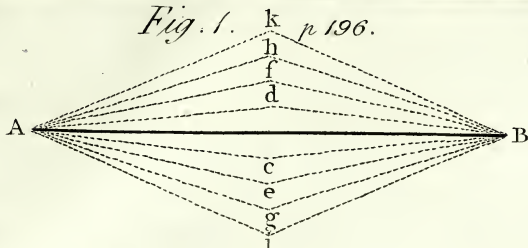
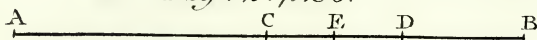
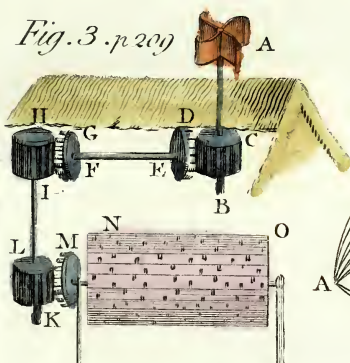
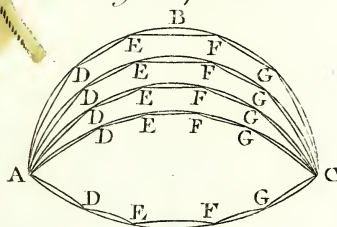
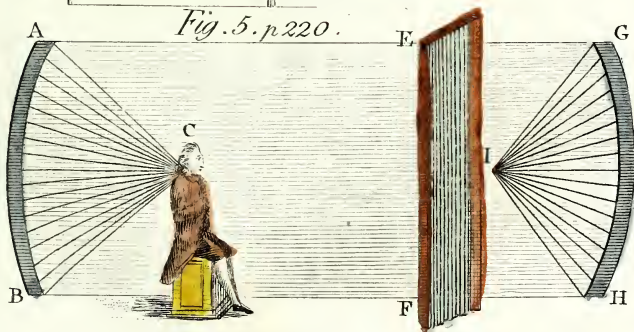
Let a person, properly instructed, be placed behind the partition near the mirror. You then propose to any one to speak softly to the statue, by putting his

illusion, the mirror AB may be fixed in the wainscot, and a gauze, or any other thin covering, thrown over it, as that will not in the least prevent the sound from being reflected.

mouth

mouth to the ear of it, assuring him that it will answer instantly. You then give the signal to the person behind the partition, who, by placing his ear to the focus I, of the mirror GH, will hear distinctly what the other said, and moving the jaw and eyes of the statue, by the wires, will return an answer directly, which will, in like manner be distinctly heard by the first speaker.

Remark. This Recreation appears to be taken from the Century of Inventions of the Marquis of Worcester; one of those men of sublime genius, who are able to perform actions infinitely superior to the capacity, or even the comprehension, of the mere scholar or man of business; and though his designs, at the time they were published, were treated with ridicule and neglect, by the great and little vulgar, who, judging by their own abilities, are ever ready to condemn what they cannot comprehend, yet

Fig. 1. p 196.*Fig. 2. p 198.**Fig. 3. p 209**Fig. 4. p 216.**Fig. 5. p 220.*



yet they are now known to be generally, if not universally, practicable. The words of the Marquis are these: “ How to make a brazen or stone head, in the midst of a great field or garden, so artificial and natural, that, though a man speak never so softly, and even whisper into the ear thereof, it will presently open its mouth, and resolve the question in French, Latin, Welch, Irish, or English, in good terms, uttering it out of its mouth, and then shut it until the next question be asked.”

R E C R E A T I O N LIX.

The Organ.

THE recreation this instrument affords is known to every one; but what we here propose is a description of the several parts of this most noble and comprehensive of all musical machines, and of the manner by which its numerous sounds
are

are produced: and such a description will, perhaps, afford a person of an ingenious disposition a recreation little inferior to the sounds themselves.

There are various sorts of organs, but that we shall here describe is the grand or church organ, which consists of two parts, the main body, called the great organ, and the positive or little organ, which forms a small case or buffet, commonly placed before the great organ. The size of an organ is generally expressed by the length of its largest pipe: thus they say, an organ of 8, 16, 32 feet, &c.*

The several parts of the church organ are as follows: **HHH** (Plate XIX. Fig. 1.) is the sound-board, which is composed of two parts, the upper board or cover **HHH**,

* The organ in the cathedral church at Ulm, in Germany, is 93 feet high, and 28 broad: its largest pipe is 13 inches diameter, and it has 16 pair of bellows.

and

and the under board H I, which is much thicker than the other ; each of these consists of several planks laid with their edges to each other, and joined very close together. In the under side of the lower board there are made several channels, which run in the direction L L, M M, &c. and are continued as far as there are stops in the organ, and come almost to the edge H K. These channels are covered over, very close, with parchment or leather, all the way, except a hole that is commonly at the fore end next H K, upon which a valve or puff is placed. These channels are called partitions. When this valve or flap is shut it keeps out the air, and admits it when open. On the upper side of the lower board there are likewise cut several broad, square channels, lying cross the former, but not so deep as to reach them ; these lie in the direction L N, P Q, &c. To fit these channels there are the same number of

wooden sliders or registers *f, f, f, &c.* running the whole length; and these may be drawn out, or thrust in, at pleasure. The number of these is the same as that of the stops in the organ.

K K K is the wind-chest, which is a square box, fitted close to the under side of the lower board, and made air tight, so that no air can get out, but what goes through the valves, along the partitions.

V V are the valves or puffs, which open into the wind-chest; they are all inclosed in it, and may be placed in any part of it, as occasion shall require. One of these valves, with the spring that shuts it and the wire that opens it, is represented by Fig. 2.

C, D, E, F, &c. are the keys on which the fingers are placed, when the organ is played: these keys lie over the horizontal
bar

bar of wood W, in which are stuck an equal number of wire pins *z z*, on which keys are fixed ; and the keys move up and down on the bar, as on a center. There is another bar, against which the keys fall when put down, and which is here marked 3: on this also are several wires which go through the keys, to guide them ; and on this bar a lift is fastened to hinder the keys from knocking against the wood.

The keys are made to communicate with the valves several ways as we shall now describe. First, *s, s, s*, are the key-rollers, moving on the pivots *t, t*: these rollers lie horizontally, one above another, and are of such a length as to reach from the valve to the key: *a, a, a*, are arms or levers fixed to the key rollers: *w, w*, the valve wires fixed to the arms *a, a*, and to the valves V, and go through the holes *h, h*, in the bottom of the wind chest: *bbb*,
 Q 2 are

are likewise arms fixed to the key-rollers: d, d, d , the key wires, fixed to the arms, b, b , and to the keys C, D, E. Now when the end of any one of the keys C, D, E, is put down, it pulls down the arm b , by the wire d , which turns about the roller s with the arm a that pulls down the wire w , which opens the valve, that is shut by the spring as soon as the pressure is taken off the key. In this construction there must be a worm-spring fastened to the key, and to the bar W, on the farther side, to keep down the end 5 , of the key.

Another method of opening the valves is thus: $x y, x y$, are slender levers, moveable on the centers $1, 1$: $5 x, 5 x$, are wires going from the farther ends of the keys to the ends x of the levers: $y V, y V$, are other wires, reaching from the ends y of the levers, through the holes h , to the valves V. So that putting down the key C, D, &c. raises the end 5 , which trusts
up

up the end x of the lever, by the wire $5x$; this depreffes the end y of the lever, which pulls down the wire yV , and opens the valve V .

A third way of opening the valves is this : at the end of the key 6 , is a lever $8, 9$, moving in the center 7 . This makes with the key, a compound lever. From] the end 9 , a wire goes to the valve. Now the putting down the end 6 of the key, raises the end 8 , which depreffes the end 9 , of the lever $8, 9$, pulls down the wire, and opens the valve. There is only one of these drawn in the scheme, and but a few of the others ; to avoid confusion.

R, R , are the rollers, to move the sliders, by help of the arms cf, cf , which are fixed horizontally in these rollers ; ke, ke , are also levers fixed in the rollers ; le, le , are the handles, which lie horizontally, and pass through the holes ll ; they are
Q 3
fastened

fastened to the lever $k e$, being moveable about a joint at e .

Now, any handle $l p$, being drawn out, pulls the end e toward l , which turns about $R k$, along with the arm $c f$; and the end f pulls out the slider $f g$; and when p is thrust in, the arm $c f$ likewise thrusts in the slider $f g$.

Upon the several rows of holes which appear on the top of the upper board, there are set up an equal number of rows of pipes. The pipes of an organ are of two kinds, the one has a mouth like a flute, the other with reeds. The first, called pipes of mutation, consist (1.) of a foot AA, BB (Fig. 3.) which is a hollow cone, that receives wind that is to sound the pipe: (2.) to this foot is fastened the body of the pipe $BB DD$. Between the foot and the body of the pipe is a diaphragm or partition FEF , that has a long
but

but narrow aperture, by which the wind comes out : over this aperture is the mouth B B C, whose upper lip C, being level, cuts the wind as it comes out.

The pipes are of pewter, of lead mixed with a twelfth part of tin, and of wood. Those of pewter are always open at their extremities : the diameter is very small, and their sound very clear and shrill. Those of lead mixed with tin are larger : the shortest are open, the longest quite stopped : those of a mean size are partly stopped, and have beside a little ear on each side the mouth, to be drawn closer or set farther asunder, in order to raise or lower the sound. The wooden pipes are square and the extremity is stopped with a valve or tampion of leather. The sound of the wooden and leaden pipes is very soft : the large ones stopped are commonly of wood, the small ones of lead. The longest pipes give the gravest sound and the shortest the most acute : their lengths and widths

are determined by a fixed proportion to their founds, and their divisions are regulated by a rule, which is called the diapason. The longest has commonly sixteen feet ; but in very large organs it has thirty-two feet. The pedal tubes are always open, though made of wood and of lead. Whatever note any open pipe sounds, when its mouth is stopped, it will sound an octave lower ; and a pipe of twice its capacity will likewise sound an octave lower.

A reed pipe consists of a foot A A B B, (Fig. 4.) that carries the wind into the shallot or reed C D, which is a hollow demi-cylinder, fitted at its extremity D, into a sort of mould, by a wooden tampion G. The shallot is covered with a plate of copper K K L L, fitted at its extremity I I, into the mould, by the same wooden tampion. Its other extremity K K, is at liberty, so that the air entering the shallot makes it tremble, or shake against the reed ; and the longer that part of the
tongue

tongue IL, which is at liberty, is made, the deeper is the found. The mould II, that serves to fix the shallot or reed, the tongue, tampion, &c. serves also to stop the foot of the pipe, and make the wind go out wholly at the reed. Lastly, in the mould is foldered the tube HH, whose inward opening is a continuation of that of the reed: the form of this tube is different in different ranks of pipes. The degree of acuteness or gravity in the found of a reed-pipe, depends on the length of the tongue, and that of the pipe CK, taken from the extremity of the shallot, to the extremity of the tube. The quantity or intension of the found depends on the width of the reed, the tongue, and the tube; as also on the thickness of the tongue, the figure of the tube, and the quantity of wind. To diversify the sounds of the pipes, a valve is added to the port-vent, which makes the wind go out in fits or shakes. In Fig. 1. X represents a flute-pipe of wood, Z a flute-pipe of metal, Y a trumpet-

pet-pipe of metal. The pipes, to prevent them from falling, pass thro' holes made in boards, placed upon the upper board.

The pipes are made to communicate with the wind-chest in the following manner. There are holes bored that go thro' the upper and lower boards, and through the slider, (when it is drawn out) into the partition below; so that any pipes placed upon those holes will then communicate with the partition, which, by its valve, communicates with the wind-chest. But when the slider is thrust in its holes do not answer to those in the upper and lower boards, therefore the communication is stopped, so that no wind can get to the pipe.

To every large organ there must be at least two pair of bellows, which are marked in Fig. 1. by *g T*, *g T*. *O*, *O*, are the handles, moving upon the axes *nn*, *nn*.

Each

Each of these bellows consists of two boards, the lowest of which is immoveable; and in this there is a valve *r*, opening inwards and a tube leading to it, called the conveying tube. There is also a hole in this under board, from which a tube leads to the port-vent, which is a square tube marked 4, rising upward, and inserted into the under side of the wind-chest at 2. In the tube leading to the port-vent there is a valve that opens toward the port-vent, and suffers the air to go up the port-vent, but not to return. Now the handle *O* being put down, raises the upper board *T*, and the air enters through the valve *r*, and when the handle is let go, the weight of the upper board, which carries three or four pound to every square foot, continually descending, drives the air through the port-vent to the sound-board: and as the bellows work alternately one pair is constantly descending, which occasions a continual blast through the port-vent. In chamber-organs there is but one pair of bellows,

bellows, but they are formed of three boards, in the manner of a smith's bellows, and so have a continual blast. All the internal structure of the organ is concealed from the sight by the front of the instrument, which stands upon the part between the numbers 3 and 6 (Fig. 1.)

In every organ the number of partitions LL, MM, &c. there are in the sound-board (Fig. 1.) that of the valves V, V; that of the rollers s, s; or of the levers x, y, or 8, 9, and their wires: and that of the keys ABC, &c. must be always equal. Large organs have commonly four or five sets of keys, beside those that belong to the pedals or large pipes, the stops to which are played by the feet. The keys of an organ are usually divided into four octaves, which are, the second sub-octave, first sub-octave, middle octave, and first octave. Each octave is divided into twelve stops or frets, of which seven are black and five white; the former mark the natural

tural notes, and the latter the artificial notes, that is, flats and sharps. The number of keys, therefore, when there are four octaves, must be 48. Some organists add one or more stops to the first and second sub-octaves. The pedals have two or three octaves, at the option of the organist; so that the number of stops is indeterminate. The keys are placed between CC (Fig. 1.) but the scheme could not contain them all. There are also as many handles *l, l*, &c. rollers *R, R*, &c. sliders *f, f*, &c. as there are stops upon the organ; and it must be observed, that between the sliders *f, f*, &c. there are as many sliders on the right hand, and the same number of handles and rollers, and other rows of pipes placed between LN, PQ, &c. which could not be expressed in the figure.

The least pipes and partitions are placed toward the middle of the organ, and the greatest on the outside. The stops
 of

of an organ have various denominations, according to the sounds they are to produce; some of which are diapason, principal, fifteen, twelve, tearce, cornet, trumpet, French horn, vox humana, flute, bassoon, Cremona, &c. There is a contrivance to swell the notes of some of the stops, by placing the treble or small pipes in a kind of chest, which is perfectly closed or opened with the foot by means of a pedal. When the pipes are close shut up, the sound is scarce audible and seems to be at a great distance; but as the chest is wholly or in part opened or closed, in a gradual and uniform manner, the sound of the pipes is increased or diminished in the same proportion. In large organs, the upper or half-row of keys belong to these pipes; and when this part is managed by a good performer, it yields the most delightful music imaginable.

When this magnificent instrument is played, the handle O of the bellows is first put down, which raises the upper board
T,

T, and gives room for the air to enter by the valve *r*. Then the other handle O is put down; in the mean time the board T, belonging to the first handle, descending, and shutting the valve *r*, drives the air, through the other valve, up the port-vent, and into the wind-chest. Then drawing out any handle, as that of the flute-stop, *pl*, which draws out the slider *fg*, all the pipes in the set LN are ready to play, as soon as the keys C,D,E, &c. are put down; therefore, if the key D be put down, it opens the corresponding valve *m V*, thro' which the air enters into the pipe X, and makes it found. In the same manner any other pipe, in the set LN, will found when its key is put down; but no pipe, in any other set, will found, till the slider be drawn out by its corresponding handle.

The organ is not only the most grand but the most ancient of all compound musical machines. Vitruvius describes an hydraulic organ in the tenth book of his architecture

chitecture, which was celebrated by the emperor Julian, in an epigram. St. Jerome mentions an organ that had twelve pair of bellows, and whose sound might be heard at the distance of a mile.

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Fig. 1 p. 224.

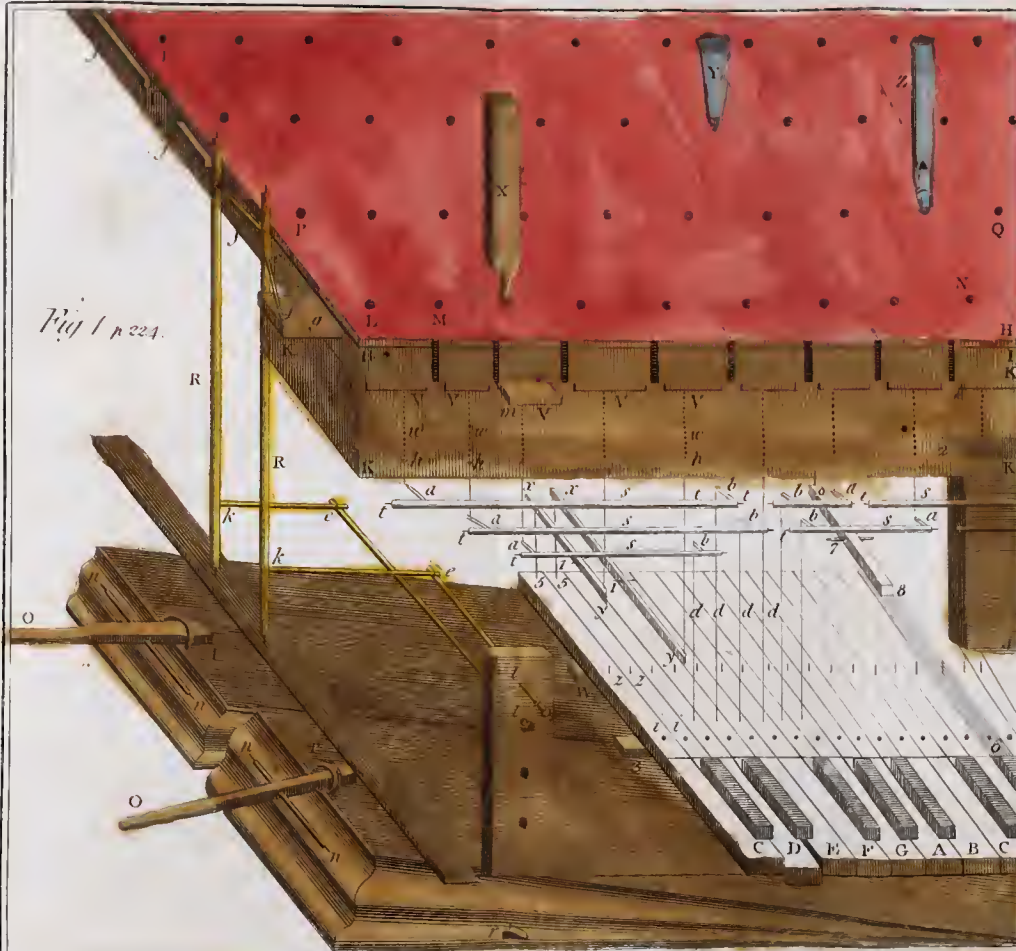


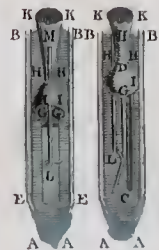
Fig. 2 p. 226.



Fig. 3 p. 230.



Fig. 4 p. 232.





T H E
C O N T E N T S.

O P T I C S.

G E N E R A L D E F I N I T I O N S	Page 1
G E N E R A L A P H O R I S M S	3

D I O P T R I C S.

D E F I N I T I O N S	5
A P H O R I S M S	7

Properties of refracted light, aph. 1 to 3	
—Properties of Lenfes, aph. 4 to 6.	
Theory of refracting telescopes	8
—— of reflecting telescopes	11
—— of microscopes	12

VOL. II. R R E-

R E C R E A T I O N I. p. 14

Optical illusion.

Three pieces of money being placed in a vessel (Pl. III. Fig. 1.) out of the view of a spectator, and water being poured into the vessel all those pieces become visible—by the refraction of the light through the water.

R E C R E A T I O N II. p. 15

Optical augmentation.

A shilling being put in a glass of water, and a plate placed upon it, the glass is turned over with the plate, and there appears a half crown on the plate and a shilling over it—by the seeing the shilling through the top and the side of the water at the same time, and the different refraction of the light.

R E C R E-

CONTENTS. 243

RECREATION III. p. 17

Optical subtraction.

Three small pieces of paper being placed against a wall, (Plate III. Fig. 2.) a person by shutting one of his eyes can see only two of them—the rays that come from one of the pieces falling always on the optic nerve, and not on the retina.

RECREATION IV. p. 18

Alternate illusion.

A silver seal when viewed through a convex lens, appears alternately engraved and in relief—conjecture on the cause of this remarkable phenomenon p. 90 (note)

RECREATION V. p. 20

The camera obscura.

A convex lens is placed in the window-shutter of a dark room, and a concave

R 2 paste-

pasteboard lined with white paper, is placed in the focus of the lens, whereby the objects without the room are painted on the paper, but inverted—method of making them appear erect, page 22 (note)—this apparatus improved by a mirror placed in different positions, p. 22—presents the most pleasing and natural of all pictures 25

RECREATION VI. p. 25

To shew the spots on the sun's disk, by its image in the camera obscura.

By placing a scioptric ball, that is, a ball of wood in which a lens is fixed, opposite the sun, which will throw its image on the paper—this image to be viewed through another lens, p. 26

R E C R E A T I O N VII. p. 27

To magnify small objects by means of the sun's rays let into a dark chamber.

By throwing the rays on a concave mirror and holding the small objects, stuck on slips of glass, near the focus of the mirror, by which means their images are reflected on the wall.

R E C R E A T I O N VIII. p. 28

The portable camera obscura.

A plate of glass is placed in a horizontal frame of wood that is supported by four legs, which fold up (Plate III. Fig. 3.) Under the frame is a box, that likewise folds up, and at the bottom of it are a tube and a mirror, by which the objects are reflected to the glass—advantage of this camera over others, p. 30—manner of drawing objects by this machine

p. 31

R 3

R E-

RECREATION IX. p. 32

The magic lantern.

The origin of this machine—it consists of a tin box, at one end of which is a concave mirror; in the other end is fixed a lens, and between them is placed a lamp: before the lens is fixed a square tin tube in which there is a groove, and through this groove the glasses that contain the objects are passed: in this tube is placed another, that is moveable, and contains two lenses, which throw the objects on a cloth—method of painting the glasses, p. 37—proposal of improving this machine by using moveable objects. p. 39

RECREATION X. p. 40

To represent a tempest by the magic lantern.

By passing two glasses, on one of which is painted the sea and sky, and on the other

other ships, (Plate IV. Fig. 1 and 2) through the groove at the same time, and giving them a proper motion—by the same method a battle, and many other subjects may be exhibited p. 42

R E C R E A T I O N XI. p. 43

The nebulous magic lantern.

At the bottom of a square box, whose height is equal to six times its width, (Plate IV. Fig. 3.) is placed a chafing-dish of hot coals, on which incense is burnt, and on the smoke that comes out of the top of the box is thrown the figures of the magic lantern.

R E C R E A T I O N XII. p. 44

To produce the appearance of a phantom, on a box or pedestal placed on a table.

A common magic lantern is placed in a box, (Plate IV. Fig. 4.) in which there is an inclined mirror, that reflects the

R 4 light

light of the lantern on the thick smoke of a chafingdish of coals placed on the box, and shows the image reflected by the glass—this Recreation must be performed in a dark room, p. 47

R E C R E A T I O N XIII. p. 48

The magical theatre.

A magic lantern must be provided that has a tube in two of its opposite sides, (Pl. IV. Fig. 5.) in one of which tubes there must be several grooves, by which the subjects to be represented may be passed either horizontally, ascending, or descending, and two or more of them at the same time. In the partition between the room where the lantern is, and that where the exhibition is to be seen, there must be placed a glass, covered with thin paper, on which the objects are to be thrown—example of a representation of the siege of Troy, in five acts, p. 52—it is quite necessary that the
glasses

C O N T E N T S. 249

glasses for these exhibitions be accurately painted, p. 60.

C A T O P T R I C S.

DEFINITIONS	62
APHORISMS	63

Properties of plain mirrors, p. 63—of
spherical convex mirrors, p. 64—of
spherical concave mirrors, p. 65.

R E C R E A T I O N XIV. p. 67

The boundless gallery.

Against each of the two smallest ends of an oblong box (Plate VI. Fig. 1.) is placed a plain mirror, and from one of them the quicksilver is taken off for the space of an inch and a half, opposite which a hole is made in the box: the top of the box is covered with glass, and between the mirrors are placed scenes properly painted, which, when viewed from the hole at the end of the
box

box appear as an endless vista or gallery.

RECREATION XV. p. 69

The four magical mirrors.

The inside of a square box (Pl. VI. Fig. 4) is lined with four mirrors : the top is covered with five planes of glass in form of the lower part of a pyramid, and on the bottom of the box are placed certain objects in relief, which, when seen from the top are so reflected by the mirrors as to form an unlimited space completely covered with objects.

RECREATION XVI. p. 72

The enchanted palace.

From the center of a hexagon to its circumference are drawn six lines, at equal distances, (Plate VII. Fig. 1.) and on each of them are fixed two mirrors, which are supported by pillars placed
at

C O N T E N T S. 251

at the circumference : the top is covered with a dome, and between the fix spaces objects are placed, which are reflected fix times, and produce a very pleasing appearance.

R E C R E A T I O N XVII. p. 75

To draw an irregular figure, which shall appear regular when viewed in a plane mirror.

The figure is to be first drawn on a square that contains a number of equal divisions, (Plate VII. Fig. 2.) and then the several parts transferred to the same number of divisions in a trapezium ; and that distorted figure, when seen in the mirror from a determinate point of view, will appear in its natural form.

R E C R E A T I O N XVIII. p. 78

The magical dial.

A dial-plate, that has a magnetic needle for a hand, is placed at the bottom
of

of a dial case and towards the top of the case is fixed a mirror, by which the figures of the hours are reflected to the part where the dial is commonly seen. Another dial plate, at the back of which is concealed an artificial magnet, that is moved by the hand of that dial, is given to a person, who setting the hand privately to any hour, puts it in a drawer at the bottom of the dial-case, under the first mentioned dial, and looking in at top he sees the reflection of the dial there, answer to the hour at which he set the other dial; the hand of the first being moved, by the attraction of the magnet in the other, to the same hour.

R E C R E A T I O N XIX. p. 81.

The box of divination.

A box that contains four cases, on each of which a number is wrote, and at the bottom of which a magnet is concealed,
(Plate

(Plate VIII. Fig. 1.) is placed on a table : under that part of the table are placed four moveable circles, that have each a needle, and under them is a drawer, that contains a mirror, so that by looking into the drawer you see, by that mirror, in what order are placed the boxes that have the numbers.

R E C R E A T I O N XX. p. 84

The magical perspectives.

A small common perspective (Plate VIII. Fig 6.) is fixed on a hollow stand of wood ; in this perspective is placed a mirror, which is moved by the inner tube, so as to show any object under the hollow stand. Three of these perspectives are set over three holes in the top of a box, (Fig. 5) at the bottom of which is placed a moveable circle, that is divided into twenty-one equal parts, and contains a magnetic needle : this box is set on a table, under which
is

is concealed a magnetic bar, that being privately placed in any position, determines that of the circle in the box, and consequently brings any of the objects painted on it under the several perspectives.

RECREATION XXI. p. 93

The penetrative perspective.

In a box or case that has two prominent parts or arms, (Plate X. Fig. 1.) are placed four mirrors, and in each of the arms is fixed the tube of a perspective glass, so that the object next the end of one perspective, being reflected by the four mirrors, is seen at the end of the other, and appears as if viewed through the two perspectives, and consequently is perfectly visible when an opaque body is placed between those two perspectives.

R E C R E A T I O N XXII. p. 96

The magician's mirrors.

Two glasses are fixed in the partition of a room, at about a foot distant from each other ; behind these glasses are placed two mirrors, inclined in a proper angle, so that a person looking into one of them, instead of seeing his own face sees that of another person who at the same time looks into the other glass. Method of improving this Recreation, by putting two glasses in adjoining rooms, p. 97—properties of plain mirrors when placed in different positions, p. 98.

R E C R E A T I O N XXIII. p. 100

Polemoscopes.

These instruments consist of a tube that contains an inclined mirror, and has an
eye

eye-glass of a proper focus, so that while the tube is pointed at one object you see another. By placing an instrument of this sort at the top of a wall, while you stand at the bottom, you see what passes on the other side, p. 101

RECREATION XXVI. p. 102

The enchanted mirrors.

In four parallel sides of a cubical box are fixed four glasses, representing mirrors, and within the box are placed two mirrors, that cross it diagonally. When four persons look into the glasses, each of them sees, instead of his own face, that of the person next him, and who appears at the same time to be placed directly opposite to him.

RECRE-

R E C R E A T I O N XXV. p. 103

The animated optic balls.

This pleasing piece of optics consists of an oblong box, (Pl. IX. Fig. 2.) three fourths of the upper part of which is divided from the lower by a horizontal partition, and is decorated with paintings. In the lower part of the remaining fourth is placed an inclined plane, in the middle of which is a serpentine groove, and in the other parts are paintings or objects in relief: in the upper part of this space is a mirror, placed in a proper angle to reflect the objects on the plane. At the end of the box is a small opening, by which ivory balls, that may be painted with different colours, are put in, and running down the groove in the inclined plane, pass out at the bottom, and are raised to the same opening again by a machine placed

Vol. II. S there

there for that purpose. Part of the top of this box is covered with glass, lined with gauze, and near the inclined plane is placed a lamp. In the end of the box opposite the plane, there is an opening in which a glass is fixed, and thro' which the objects on the inclined plane are seen, reflected by the mirror, and being all inverted, the balls seem to roll up the mirror, and pass out at the top of the box.

R E C R E A T I O N XXVI. p. III

The optic balls by a double reflection.

This box differs from the last in having a mirror where the inclined plane is there placed, and in the planes being placed at the opposite end of the box. There may also be an additional number of grooves, with a small inclination, thro' which the balls may pass: and if there be sufficient room, there may be two sets of grooves, by which the balls will seem in the mirror to rencounter and pass over each other.

R E C R E-

R E C R E A T I O N XXVII. p. 114

To describe on a plane surface an irregular figure, which shall appear regular when placed opposite a multiplying glass, and seen by reflection through an aperture made in the center of the drawing.

The plan of the multiplying glass (Plate X. Fig. 4.) being drawn on paper, the design is to be drawn on that. The glass is to be fixed on a stand at one end of a box, and at the other end is to be a frame that holds a paper, in the middle of which is a hole, and on which is to be transferred the design drawn on the multiplying glass, and which will then be quite distorted ; but being seen in the mirror, by looking through the hole, it will appear quite regular.

R E C R E A T I O N XXVIII. p. 120

To describe on a plane surface a deformed figure, which shall appear regular when viewed by reflection in a cylindrical mirror.

Part of the surface of the cylinder (Pl. XI. Fig. 1.) is to be divided by lines, into twelve parts, in proportion to those of the diameter of the circle CD, Fig. 2. The paralelogram, Fig. 3. is likewise to be divided into twelve equal parts, and on them a regular figure is to be drawn, and then transferred to the same number of parts, which will be reflected on the plane DG, by the lines on the cylinder, and the figure will then appear deformed, but being seen from the point of view E, will be quite regular. A similar experiment may be made with prismatic and other mirrors, p. 124

R E C R E-

RECREATION XXIX. p. 123

Optical appearances.

A bottle half full of water being placed near the focus of a concave mirror, appears not only inverted, but the water at the top of the bottle, and the bottom of the bottle empty. If the bottle be inverted and placed before the mirror its image will appear erect, and the water at the bottom of the bottle. If while the bottle is inverted it be uncorked, it will appear, that while the upper part is emptying the bottom part is filling.

RECREATION XXX. p. 128

The perspective mirror.

At one end of an oblong box (Plate XII. Fig. 1.) is placed a concave mirror; near the upper part of the opposite end a hole is made, and about the middle of the box is placed a hollow frame of

pasteboard, that confines the view of the mirror. The top of the box next that end in which the hole is made is covered with a glass; and under the hole are placed, in succession, different pictures, properly painted, which are thrown into perspective by the mirror, and produce an appearance that is highly pleasing.

RECREATION XXXI. p. 130

To set fire to a combustible body, by the reflection of two concave mirrors.

These two mirrors (Plate XII. Fig. 2.) are placed at a considerable distance, and in the focus of one of them is put a live coal, in that of the other some gunpowder and by the blowing on the coal, the gunpowder will take fire, though the distance between the mirrors be several feet.

RECRE-

CONTENTS. 263

RECREATION XXXII. p. 132

The real apparition.

A hole is made in a partition, (Plate XII. Fig. 3.) and behind it is placed a large concave mirror, and a strong light, that must not be visible at the hole. On the same side of the partition, and directly under the hole, is fixed, in an inverted position the object that is to appear without the partition. A person being placed in a proper point of view will see the object on the outside, and in an erect position.—The figure of an absent or deceased friend may be made to appear by this method, p. 134—The imaginary combat by a concave mirror, p. 136

CHROMATICS.

DEFINITIONS	p. 137
APHORISMS	138

RECREATION XXXIII. p. 140

Out of a single colourless ray of light to produce seven other rays, which shall paint, on a white body, the seven primary colours of nature.

A round hole is made in the window-shutter of a dark room, and the ray of light that enters at the hole, falling on a prism, is refracted, and being thrown on a paper placed at a proper distance, forms an oblong spectrum that exhibits all the primary colours of nature.

RECREATION XXXIV. p. 142

From two or more of the primary colours to compose others that shall, in appearance, resemble those of the prism.

By mixing any two of the primary colours, as yellow and blue, the intermediate colour, green, will be formed ; but these mixed colours, though similar in appearance to the primary, yet when
viewed

viewed through a prism, are resolved into the colours of which they are composed.

RECREATION XXXV. p. 144

Out of the three primary colours, red, yellow and blue, to produce all the other prismatic colours, and all that are intermediate to them.

Three panes of glass are divided, each of them into five equal parts, and over those parts are pasted a different number of papers painted either red, yellow, or blue, (Pl. XIII. Fig. 2.) When one of these glasses is put in a box, open at two opposite ends, all the gradations of the colour it contains are visible; and when two of them are placed together, Fig. 3, the intermediate colour appears with its several degrees.

RECREATION XXXVI. p. 147

By means of the three primary colours, red, yellow, and blue, together with light and shade,

shade, to produce all the gradations of the prismatic colours.

On seven square panes of glass papers are pasted that contain all the prismatic colours, and over them are put a different number of pieces, tinged with a deep shade, and they are then placed in a box, in the same manner as in the last Recreation. Method of printing in colours, p. 148.

RECREATION XXXVII. p. 150

The magical prism.

A ray of light that comes through a hole made in the window-shutter of a dark-chamber, falling on a glass prism, (Plate XIII. Fig. 4.) is refracted on a hollow prism of wood, that revolves on an axis, and in whose sides figures are cut. As this prism changes its position with regard to that of the glass, the figures cut out will appear white, yellow, and red, or blue and violet.

R E C R E -

R E C R E A T I O N XXXVIII. p. 152

The solar magic lantern.

A small box that is open at two opposite sides, is placed against a hole of the same size in the window-shutter of a dark chamber, that faces the sun. Through this box are passed, by a groove, pasteboard blacked, and through which different figures are cut. These figures, when viewed through a prism, appear to be painted with the most lively colours in nature. This Recreation may be diversified by pasting papers tinged with different colours, over the figures in the pasteboard.

R E C R E A T I O N XXXIX. p. 154

The artificial rainbow.

Opposite a window on which the sun shines, a glass globe filled with water is suspended by a string that passes over a pulley ; and when it is drawn up to a certain height, which may be found by trial,

trial, the colours of the rainbow will appear in it : when it is drawn up a little higher the colours disappear, and when it is drawn up still higher they appear again, and at last totally disappear. The phenomena of the natural rainbow explained by this experiment, p. 155

RECREATION XL. p. 158

The prismatic camera obscura.

Two holes are made in the shutter of a dark chamber (Plate XIII. Fig. 5.) and against each of them a prism is placed, in such manner that both their spectrums are cast upon the same spot. Several papers, of the same dimension with the spectrums, have lines drawn on them parallel to the divisions of the colours, and between those divisions figures are cut out, which then appear to be painted with all the primary colours. This Recreation may be diversified by turning one of the prisms round ; and by looking at the spectrums through another prism, p. 159.

R E-

R E C R E A T I O N XLI. p. 160

The diatonic scale of colours.

The sun's spectrum is to be largely refracted on a paper, and the divisions of the several colours set off, when they will be found to correspond to the divisions of a musical chord for the notes of an octave.

R E C R E A T I O N XLII. p. 162

Colorific music.

The surface of a hollow cylinder (Plate XIV. Fig. 2.) is divided vertically into six equal parts, and horizontally into forty-one parts; in each of the latter parts spaces are cut, over which are pasted papers that are painted with the seven primary colours. At the bottom of this cylinder is a wheel, an endless screw, and a nut; and when it is placed in a case, Fig. 3, the endless screw is
turned

turned by a handle, which turns the wheel, and raises the cylinder by means of the nut at bottom, the height of five of its horizontal divisions, and consequently shows the several colours it contains at the eight apertures made in the front of the case. A lamp is suspended from the top of the case, which hanging within the cylinder, shows the colours that answer to the notes of music, and the length of those colours corresponds to the duration of the notes.

PERSPECTIVE RECREATIONS.

R E C R E A T I O N XLIII. p. 168

To draw on a plane surface an irregular figure, which, when seen from a proper point of view, will appear similar to a given figure.

A paralelogram is divided into forty-eight equal parts, (Plate XV. Fig. 1.) on which the regular figure is drawn, and
its

its feveral parts tranfposed, to an equal number of divifions in a trapezium, where the figure will appear deformed, but when feen from a proper point of view, quite regular. The correfponding parts in the parallelogram and trapezium are to be numbered, p. 172—Thefe figures appear to great advantage when painted on the fide of a gallery, p. 174.

R E C R E A T I O N XLIV. p. 175

To draw an irregular figure on a plane, which being feen from two oppofite points of view, fhall represent two different regulations.

The two regular fquares are to be firft drawn on the two parallelograms. (Pl. XVI. Fig. 3.) and then transferred to the divifions of the paralellogram, Fig. 2. On a board Fig. 4, of the fame fize with the laft figure, lines are cut, in
which

which a paper, Fig. 5, is pasted, and the distorted figure on it: which when seen from two proper points of view, will present two regular figures.

RECREATION XLV. p. 181

To draw on the base of a cone, an irregular figure, which shall appear, when seen from a proper point of view, not only regular, but elevated above the surface of the cone.

The cone is placed in a board, (Pl. XVII. Fig. 1.) with its base upward, and at one end of it is fixed a perpendicular plate of glass, on which the regular figure is drawn. At the point of view a lamp is placed, by which the figure on the glass is thrown on the base of the cone, and there traced. The lamp and glass are then taken away, and the distorted figure, when seen from the point of view appears not only regular, but
erect

erect, and in the same situation it was on the glass.

R E C R E A T I O N XLVI. p. 186

To draw, easily and correctly, a landscape, or any other object, without being obliged to observe the rules of perspective, and without the aid of the camera obscura.

In the largest end of a box (Plate XVII. Fig. 3.) there is a frame, divided into a number of equal divisions, and in the opposite end is a tube. This box is supported on a stand. You are provided with a paper that has the same number of divisions as the frame in the box, and looking through the tube you transfer the several objects seen through the divisions of the frame to those on the paper.

R E C R E A T I O N XLVII. p. 189.

Illuminated prospects.

The top of a print, properly painted, is cut off, and put in a frame, and the lower part in another frame. These two frames

Vol. II. T are

are placed in a box, (Pl. XVII. Fig. 5.) at different distances, and behind them lights are set, and when they are viewed from the front of the box, and there is no other light in the room, they afford a very pleasing appearance.

RECREATION XLVIII. p. 191

Transparent illuminations.

Those parts of a print where the light is to appear are cut through with a fine tool. The print is then put in a frame and placed in the box described in the last recreation: behind it is a yellow transparent paper, and behind that are lights. These scenes are to be moveable, so as to represent a succession of objects differently illuminated.

A C O U S T I C S.

DEFINITIONS

p. 195

APHORISMS

196

Nature of sonorous bodies, aph. 1 to 5.—

Vibrations of chords, aph. 6 to 9.—Pro-

pagation of sound, aph. 10 to 14.—

Strength and reflection of sound, aph.

15 and 16.

R E-

RECREATION XLIX. p. 201

The eolipiles.

A small metal globe, with a slender neck, is thrown when hot, into a vessel of water, and when it is put on a fire the water rushes out with a great noise—this phenomenon improved by fixing the calls used by fowlers to the necks of these eolipiles.

RECREATION L. p. 202

The communicative busts.

Two busts are placed on pedestals on the opposite sides of a room, and from the mouth of the one there goes a tube under the floor, to the ear of the other. Therefore, if a person speak into the ear of one bust, another person, who applies his ear to the mouth of the other bust, will hear distinctly all the first utters; and at the same time other people, in the middle of the room, will hear nothing of what passes.

R E C R E A T I O N LI. p. 203

The oracular head.

This recreation is performed by a single head, and tubes, that go from the ear and mouth of it, to a room underneath, where a confederate hears what is said, and returns an answer; and there are wires by which the eyes and lips of the bust are moved at the same time.

R E C R E A T I O N LII. p. 204

The solar sonata.

A barrel organ is placed in a case, that has a glass front, behind which is a tube with spirits, and on that a cork floats, which, when it rises to a certain point, by the heat of the sun, lifts up a catch, and sets the organ in play; but when the machine is carried into the cold the spirits sink, and the catch again stops the organ.

R E C R E A T I O N LIII. p. 207

An automatus harpsichord.

There are wires that go from the under part of the keys of a harpsichord, and a
barrel

barrel with pins, that take the ends of those wires. Round the axis of the barrel goes a string, that passes under the floor, and communicates with a smoke-jack, by which the harpsichord is played incessantly.

R E C R E A T I O N LIV. p. 209

A ventosal symphony.

On the top of a house there is a vane, (Pl. XVIII. Fig. 3.) at the bottom of which, and within the roof of the house, is a wheel that communicates, by other small wheels and pinions, with a large barrel in the room underneath : to this barrel a number of stops are fixed, and close to it are hung twelve bells ; therefore as the vane is turned by the wind, the several small wheels being put in motion, turn the barrel, and by making it strike the bells, according to the position of the stops, play the symphony.

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R E C R E A T I O N LV. p. 211

The nocturnal reveilleur.

On the circumference of a wheel are placed a number of bells, and round its axis is wound a rope, at the end of which is fastened a weight that rests upon one end of a moveable lever, and is balanced by a hollow cone, filled with sand, hung to the other end of the lever, but as the sand runs out the weight descends and by turning the wheel rings the bells.

R E C R E A T I O N LVI. p. 214

A musical cascade.

A large wheel is placed under a cascade, the water of which is confined to the ends of the wheel; the middle of this wheel consists of bars, in which stops are placed, that by striking a certain number of bells play one or more tunes, at pleasure.

R E C R E A T I O N LVII. p. 216

Reverberated sounds.

Construction of a whispering gallery—the nature of echoes, p. 217—of reverberated echoes, p. 219.

R E C R E A T I O N LVIII. p. 220

The converse statue.

There are two large concave mirrors, and in the focus of one of them is placed the figure of a man (Pl. XVIII. Fig. 5.) The other mirror is placed behind a partition, in which is an opening, concealed by a gauze. When a person speaks softly in the ear of the statue, which is exactly in the focus of one of the mirrors, another person placing his ear in the focus of the other mirror will hear distinctly what is said, and answering softly at the same point will be heard by the first person.

R E C R E A T I O N LIX. p. 223

The great organ.

The body of this noble instrument consists of a wind-chest, (Pl. XIX. Fig. 1.) over which is placed two boards, that form what is called the sound-board. in the under side of the lower board are several partitions, and in its upper side
are

are cut channels, in which sliders are placed, in a transverse position to the partitions. There are holes made thro' the upper board, sliders and under board, into the partitions; and in the holes of the upper board the pipes are placed that produce the sounds. There are two pair of bellows, by which the air is forced into the chest. When any one of the sliders is drawn out, its holes correspond with those in the upper board and in the partitions. At the front end of each partition is a valve, under which is a hole into the wind-chest; these valves are connected with the keys of the organ by wires, so that when a key is put down it opens a valve and the air rushes into the partition, and the slider being drawn out it passes through the holes in that and the upper board into the pipe placed over it, and makes it sound.

THE END OF THE SECOND VOLUME.







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